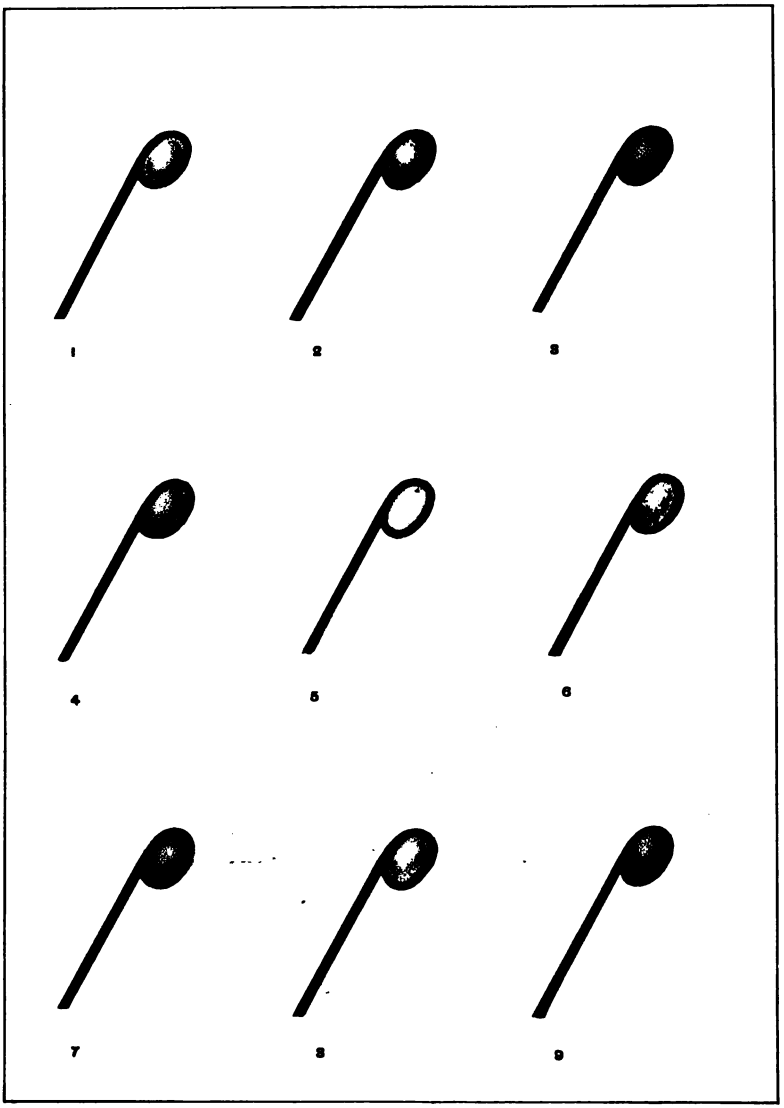
GUIDE FOR

PROSPECTORS, EXPLORERS, AND MINERS



C. Wilson Moore. del.

SOME BORAX BEADS.

1. COBALT - (O.F. HOT.).
2. CUPRITE (,, ,,).
3. MAGNETITE (,, ,,).
4. MANGANESE (O.F. HOT.).
5. MOLYBDENUM (,, ,,).
6. NICKEL (O.F. + R.F. COLD).
7. MOLYBDENUM (O.F. + R.F. COLD).
8. BORACITE (O.F. + COBALT NITRATE).
9. TITANIUM (R.F. COLD.).

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1898

A PRACTICAL GUIDE

FOR

PROSPECTORS, EXPLORERS, AND MINERS

A MANUAL FOR ALL THOSE ENGAGED OR INTERESTED IN THE SEARCH FOR OR DEVELOPMENT OF METALLIC AND OTHER MINERAL DEPOSITS

BY

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WITH NUMEROUS ILLUSTRATIONS BY
C. & A. P. WILSON MOORE

LONDON
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PREFACE

THIS little work lays no claim to rank among the scientific books of the day. Originally designed for South Africans only, it has been enlarged with a view of providing those to whom a scientific education has, from various causes, been unattainable, with the knowledge necessary for prosecuting an intelligent search for minerals.

The simplest language and easiest classifications have been adopted, and an attempt has been made to render all the subjects as interesting as possible. In addition to personally acquired experience and knowledge in various countries and schools, the best authors and authorities on various subjects have been diligently consulted.

I am unaware of any book in the English language which systematically covers the ground which it is believed this one will.

Commencing by explaining simply the chief chemical laws which govern and regulate the composition of minerals and rocks, a description of the chief minerals and rocks is then given, and their composition, physical characteristics and occurrences, fully dealt with. The structure of the earth's crust, the natural modifying causes, and the records of geological history, are explained in simple language, and a chapter is added on Mineral Veins.

In addition to assaying, the use of the 'poor man's laboratory'—the blowpipe—is explained, and useful hints are given upon prospecting, developing, surveying, blasting and water-

power. Some useful tables and a glossary of mining terms conclude the work.

By a study of these chapters it is believed that any intelligent prospector will be able to recognise, test, and often locate in its proper geological place, any mineral or rock he may find, without the loss of time and money entailed by a return to head-quarters; and further, it is hoped that prospectors and explorers may be saved, by their agency, many a fruitless search in barren formations.

It is, perhaps, true that most of the mineral deposits of the world have been found 'by luck;' but when one remembers the large number of prospectors at work, it would be indeed strange if some 'good finds' were not made among the many disappointments. Might not the proportion of successful prospectors be larger if a better rudimentary knowledge on these subjects were more general among them?

I am aware that this book falls short in many particulars; but if it is successful in increasing the number of 'good finds,' and in leading to a more intelligent and less wasteful method —both in toil and money—of searching for minerals, I shall consider my labour well repaid.

Perhaps, too, it may be the means of inducing some to find pleasure as well as profit in the scientific study of the geological history of our planet.

I am indebted for much information to the works of Professor Geikie, LL.D., Professor Page, LL.D., and James D. Dana, to whose more advanced works the student is referred for more detailed knowledge.

In the chemical sections of this work I have received valuable assistance from Mr. John H. Powell, A.R.S.M.

My sincerest thanks are due to Mr. Ernest Moore Wilson, M.S.E., for having so kindly corrected the proofs for me in England.

CUNINGHAME WILSON MOORE.

SOUTH AFRICA, 1893.

CONTENTS

SECTION I.

CHEMISTRY.

CHAPTER I.

CHEMICAL LAWS AND DATA.

CHAPTER II.

GASEOUS AND LIQUID ELEMENTS AND COMPOUNDS.

SECTION II.

MINERALOGY.

CHAPTER I.

PHYSICAL PROPERTIES OF MINERALS.

CHAPTER II.

DESCRIPTION OF MINERALS (ACIDIC AND BASIC GROUPS).

CHAPTER III.

DESCRIPTION OF MINERALS (SILICA AND SILICATES, HYDROCARBONS).

SECTION III.

PETROLOGY.

SECTION IV.

GEOLOGY.

CHAPTER I.

MODIFYING CAUSES AT WORK UPON THE EARTH.

CHAPTER II.

THE STRUCTURE OF THE EARTH'S CRUST.

CHAPTER III.

MINERAL VEINS AND DEPOSITS.

CHAPTER IV.

GEOLOGICAL HISTORY.

SECTION V.

ASSAYING AND BLOWPIPE ANALYSIS.

CHAPTER I.

ASSAY APPARATUS AND ASSAYING.

CHAPTER II.

BLOWPIPE ANALYSIS.

SECTION VI.

PROSPECTING, &c.

CHAPTER I.

PROSPECTING, DEVELOPING, &C.

CHAPTER II.

LIST OF ILLUSTRATIONS

FULL-PAGE PLATES

ILLUSTRATIONS IN TEXT

A

PRACTICAL GUIDE

FOR

PROSPECTORS, EXPLORERS, AND MINERS

SECTION I

CHEMISTRY

CHAPTER I

Chemical Laws and Data

The science of chemistry, as a whole, treats of the composition of substances and the changes which they undergo.

Organic chemistry deals with the substances forming the structure of organised beings, such as plants and animals, the scope of which does not fall within the limits of this work.

Inorganic chemistry is the study of inorganic or mineral substances, and is either analytical or applied.

Analytical inorganic chemistry is the science which teaches the division of compound substances into their simple elements; *applied* inorganic chemistry treats of the manufacture and application of substances as commercial products.

An elementary knowledge of the chief chemical laws is necessary for the intelligent understanding of the chapters in this book dealing with mineralogy, petrology, geology, and

assaying; therefore, while the purpose of the chemist is to examine, by experiment, the properties of all substances with reference to their action under varying circumstances, the object of this book will be served by dealing briefly with the fundamental laws governing the chemical combination and the examination of the elements and their compounds.

Excepting in the cases of the gaseous elements (and their gaseous and liquid compounds), the elements and their solid compounds, their occurrences, uses, physical properties, and simple methods of determining the nature of each, will be dealt with under the heading of mineralogy.

All substances are divided by the chemist into two great groups—

1. *Compound substances*, which can be split up into two or more essentially different materials.

2. *Simple substances* or *elements*, which cannot be thus split up, and from which no substance can be obtained essentially differing from the original.

Compound bodies are made up of two or more elements chemically combined. Water, iron pyrites, and mercuric oxide are examples.

Water, under natural conditions, exists as a solid, liquid or vapour, but by chemical means it can be split up into two gases—hydrogen and oxygen—each being totally different from the original substance. Iron pyrites can be resolved into two elements—iron and sulphur—and mercuric oxide into the metal mercury and the gas oxygen.

The decomposition of the latter substance can be readily seen by the following experiment:—Place a little of the compound into a test tube and then heat strongly for a few minutes; the mercury will sublime in small globules on the cool sides of the tube, while the presence of the oxygen is indicated by plunging a glowing match into the mouth of the tube, when it will immediately burst into brilliant flame. Thus the mercuric oxide splits up into two elements—oxygen and mercury—and these two elements when combined as the oxide weigh exactly the same as they do when separated. This last fact as to the unaltered weight of the elements, either combined or separated, points to the conclusion that in nature

there is no loss or waste of material even under altered conditions. This fact is called by chemists '*the indestructibility of matter*,' and it was one of the first established fundamental laws of chemical science.

The substances of which a candle is formed consist almost entirely of carbon and hydrogen, and the act of burning is the result of the combination of these two elements with the oxygen of the atmosphere, forming aqueous vapour and carbon dioxide. These products of the combustion can be collected, and it can be shown that their weight together is exactly equal to the weight of the candle consumed *plus* the weight of the oxygen taken from the air to form the combustion. Thus, although there is a visible and actual alteration in the state of the bodies, no part of them has been destroyed.

Of the simple substances, or elements, more than seventy are at present (1890) known to chemists. The number is likely to be increased rather than decreased, but many are extremely rare, have no commercial value, and are chiefly interesting as chemical curiosities.

The following is a complete list of the known elements, with their symbols and atomic weights. The more common metals are shown in large capital letters, the others in small capital letters; the more common non-metallic elements are shown in large italics, the less common in small italics.

Name	Symbol	Atomic weight
ALUMINIUM	Al	27·0
ANTIMONY	Sb (Stibium)	120·0
ARSENIC	As	74·9
BARIUM	Ba	136·8
BERYLLIUM	Be	9·2
BISMUTH	Bi	208·0
BORON	B	11·0
BROMINE	Br	79·75
CADMIUM	Cd	111·9
CÆSIUM	Cs	133·0
CERIUM	Ce	139·9
CALCIUM	Ca	39·9
CARBON	C	11·97
CHLORINE	Cl	35·37
CHROMIUM	Cr	52·1
COBALT	Co	58·6
COPPER	Cu (Cuprum)	63·1
DIDYMIUM	D	142·0
ERBIUM	E	166·0

Name	Symbol	Atomic weight
FLUORINE	F	19·1
GALLIUM	G	69·8
GOLD	Au (Aurum)	196·2
HYDROGEN	H	1·0
INDIUM	In	113·4
IODINE	I	126·53
IRIDIUM	Ir	192·7
IRON	Fe (Ferrum)	55·9
LANTHANUM	La	138·0
LEAD	Pb (Plumbum)	206·4
LITHIUM	Li	7·01
MAGNESIUM	Mg	24·3
MANGANESE	Mn	55·0
MERCURY	Hg (Hydrargyrum)	199·8
MOLYBDENUM	Mo	95·8
NICKEL	Ni	58·6
NIOBIUM	Nb	94·0
NITROGEN	N	14·01
OSMIUM	Os	198·6
OXYGEN	O	15·96
PALLADIUM	Pd	106·2
PHOSPHORUS	P	30·96
PLATINUM	Pt	194·5
POTASSIUM	K (Kalium)	39·04
RHODIUM	Rh	104·1
RUBIDIUM	Rb	85·2
RUTHENIUM	Ru	103·5
SCANDIUM	Sc	44·0
SELENIUM	Se	78·0
SILVER	Ag (Argentum)	107·66
SILICON	Si	28·0
SODIUM	Na (Natrium)	22·99
STRONTIUM	Sr	87·2
SULPHUR	S	31·98
TANTALUM	Ta	182·0
TELLURIUM	Te	125·0
TERBIUM	Tb	148·5
THALLIUM	Tl	203·6
THORIUM	Th	231·5
TIN	Sn (Stannum)	117·8
TITANIUM	Ti	48·0
TUNGSTEN	W (Wolfram)	184·0
URANIUM	U	240·0
VANADIUM	V	51·2
YTTERBIUM	Yb	173·2
YTTRIUM	Y	89·0
ZINC	Zn	65·1
ZIRCONIUM	Zr	90·0

In addition to the above there are the following very rare metals:—Actinium, Gadolinium, Germanium, Helium, Holmium, Idunium, Ilmenium, Neptunium, Norwegium, and Samarium.

The crust of the earth, which contains all these elements as simple or compound substances, is formed almost entirely of the following eight elements.

Average Composition of the Solid Crust of the Earth in 100 *parts by weight.*

Oxygen	46·4 parts	Calcium	3·3 parts
Silicon	29·6 „	Magnesium	2·2 „
Aluminium	8·2 „	Sodium	2·2 „
Iron	6·2 „	Potassium	1·5 „

It will be seen from the above table that more than three-fourths of the substances forming the earth's solid crust consist of two elements—oxygen and silicon—while, excluding the above-mentioned eight elements, the whole of the others would not form one per cent. of the total weight.

Symbols.—With the object of expressing in a more concise manner the composition of chemical compounds than could be done by writing in full the names of the combining elements, chemists have adopted a kind of shorthand which greatly simplifies the expression of chemical changes or reactions. Thus, instead of writing the whole name, the first letter (or, where there are a number of compounds beginning with the same initial, the first and another prominent letter) in the name of an element is used. In this way O stands for oxygen, Cl for chlorine, Pt for platinum, and Au for gold (*aurum* being the Latin word for this metal).

But these letters signify much more than this. They stand not only for the full names of the elements in question, but they stand also for certain numbers which represent the proportions in which these elements combine together to form compounds. For example, the symbol O does not merely stand for the name of the substance oxygen or any indefinite weight of it, nor for any absolute weight expressed in pounds and ounces. It denotes as well that the smallest quantity by weight of oxygen which can enter into combination with any element or compound is exactly 15·96 times as heavy as the smallest quantity of hydrogen (which is the unit, or 1) which can also enter into combination. In this way the

symbol of a compound not only expresses its *qualitative* but also its *quantitative* composition.

The symbol for water is written H_2O, and this means that water consists of the two elements hydrogen and oxygen in combination in the following proportions:—

$$\begin{aligned} \text{oxygen} &= 15{\cdot}96 \\ \text{hydrogen} \times 2 &= 2 \end{aligned}$$

or, in other words, two parts of hydrogen unite with 15·96 parts of oxygen to form the compound we know as water. In the symbol above, (H_2O) the small figure $_2$ placed below the letter H signifies that the element hydrogen has to be taken twice over; in other words, that it requires *two* parts of hydrogen to enter into combination with the oxygen to form water. The sum of the atomic weights of the elementary constituents, in this case 17·96, is called the *combining weight of the compound.* In a similar manner, each of the elements has its symbol and its atomic weight.

Of the reasons which have led chemists to adopt these various symbols and numbers and of the laws which have been found to regulate their combination we shall only give a brief outline, as to discuss them fully would be beyond the scope of this work.

Dalton's atomic theory.—Matter is made up of small indivisible portions, which are called *atoms.* These atoms do not all possess the same weights, but the relation between their weights is represented by the combining weights of the elements which are thus known as the *atomic weights.* Thus, by referring to the list of the elements, it will be seen that the atom of oxygen is taken to be 15·96 times as heavy as the atom of hydrogen; and the weights of the atoms of nitrogen and iron are as 14·01 to 55·9.

The smallest particle of a chemical compound consists of a group of separate atoms, and this group is called a *molecule.* It is supposed to be indivisible by mechanical force, but can be separated into its constituent atoms by chemical means. Thus the molecule of water consists, as we have seen, of two atoms of hydrogen and one atom of oxygen and the sum of

their atomic weights, viz. $(1 \times 2 =)2 + 15{\cdot}96 = 17{\cdot}96$, which is the *molecular weight of water.*

Density of gases.—The various gaseous elements have different densities; the weight of a given volume of hydrogen under a given temperature and pressure being taken as 1, then the densities of the other gases are indicated by the weight of the same volume under the same conditions of temperature and pressure. Experiments conducted on this basis have proved that, the weight of a cubic inch of hydrogen being considered as the unit, the weights of a cubic inch of oxygen and nitrogen will be 15·96 and 14·01 respectively, and the densities of all gases and gaseous compounds, although they do not all correspond to their atomic weights as do these two, have been calculated in a similar manner.

The density of a gas varies with the temperature and pressure. Gases expand $\frac{1}{273}$ part of their volume at 0° Centigrade, or 32° Fahrenheit, for every increase in temperature of 1° Centigrade; and in a similar degree the volume is decreased by a lowering of the temperature. When a gas is subjected to an increase of pressure its volume becomes less, and when the pressure is decreased the volume of the gas increases. The law which governs this increase or decrease of volume is as follows:—

The volume of a gas is inversely proportional to the pressure to which it is subjected.

Thus *one* volume of gas under a pressure equal to the atmospheric pressure becomes *two* volumes if under one half the atmospheric pressure, or only *half* a volume if under a pressure equal to two atmospheres.

Thermometers.—The instrument by which we measure temperature is known as the thermometer. Its use depends upon the expansion or contraction which bodies undergo when they are heated or cooled. Mercury and alcohol are the substances usually employed in the manufacture of the expansive parts of thermometers, as their use has many advantages over other liquids. A piece of glass tubing with a bulb on one end, open at the other, and with a small hole of uniform size through the centre, is filled with mercury (or alcohol) and heated to the highest temperature which the instrument is

required to measure; the open end is then hermetically sealed. In order to graduate or mark the heights of the mercury at different temperatures upon the tube, it is first plunged into finely powdered melting ice, and a mark is made at the point where the mercury stands; the bulb and stem are then immersed in steam from boiling water and another mark is made; these two points are, respectively, the freezing and the boiling points. The space between these two points is then subdivided, the number of divisions depending upon the scale adopted.

Three scales are in general use: (1) the Centigrade scale, (2) the Réaumur scale, (3) the Fahrenheit scale. In the Centigrade scale, which is commonly employed in scientific work, the space between the two points is divided into 100 equal parts, the zero of the scale is placed at the freezing-point, and the boiling-point is therefore 100° C. In Réaumur's scale the same space is divided into 80 equal points, the zero being again placed at the freezing-point, so that the boiling-point on this scale will read 80° R.

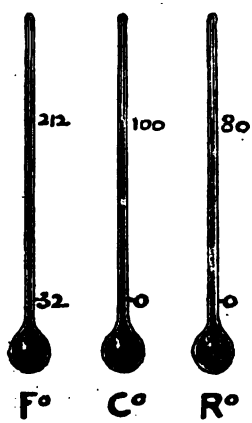

Fig. 1.—Thermometers.

The freezing-point in Fahrenheit's scale is marked 32° F., and the boiling point 212° F., so that there are 180 equal divisions between these two points in this scale. The zero in a Fahrenheit scale is 32° of these divisions below the freezing-point, and arose from the fact that at this point Fahrenheit conceived the mistaken idea that he had arrived at the lowest possible temperature.

In fig. 1 the relative markings of these scales are depicted (see also page 271).

Barometers.—The pressure of the atmosphere is measured by an instrument named the barometer. In its simplest form a barometer consists of a straight glass tube, about thirty-two inches in length, with a graduated inch scale. This tube is completely filled with clean and dry mercury,

and the open end placed in a vessel containing the same metal, the tube being held in a vertical position, as in fig. 2. If the experiment be made at or near sea-level, the mercury will be seen to sink in the tube to a point about thirty inches above the level of the mercury in the vessel, this being the average amount of atmospheric pressure at sea-level. When the atmospheric pressure increases, the column of mercury in the tube naturally rises; and when the pressure decreases the column falls.

FIG. 2.—Simple Barometer.

Now it may be asked, How is it that the atmosphere exerts this pressure? It is the weight of a column of air of the same diameter as the column of mercury in the tube, but of enormously greater length, extending, in fact, to the boundary of the atmospheric envelope encircling the earth. The air has weight, like any other body, but inasmuch as we are filled with and completely surrounded by it, this weight does not, under ordinary circumstances, make itself felt. But in the case of the mercury in the tube it is different; not being, in fact, surrounded with this pressure, it feels it in whatever direction it comes, and it registers the change and density of the length of this air column in the way indicated. If we ascend a hill the pressure of the atmosphere becomes less, because there is, of course, less of it above us, and the barometer would in consequence fall as it was carried above sea-level. This fact is made use of for measuring heights roughly by means of this instrument, and is alluded to more particularly under Section VI. (see page 258).

Vapour tension.—If a small quantity of water be placed above the mercury in a barometer, and be then gradually heated, the column of mercury will be seen to fall; when the water has reached its boiling-point the level of the mercury inside the tube will be the same as that in the vessel outside; so that we see the vapour of the water (or the steam) is now exerting a pressure exactly equal to the pressure of the atmosphere. This power of water vapour to exert pressure is termed *the tension of aqueous vapour*, and water is therefore

said to boil when the tension of its vapour is equal to the atmospheric pressure. In the last paragraph we saw that the atmospheric pressure decreased as we ascended from the sea-level, and that the barometer registered the amount of this decrease; it is therefore certain, bearing in mind the law as to the tension of aqueous vapour, that water will boil at a lower temperature on the top of a hill than it will at sea-level. Under normal conditions, water boils at a temperature of 212° F. at sea-level, and, roughly speaking, for every 530 feet we ascend the boiling-point falls 1° F.; thus, on the top of a mountain 6,360 feet high, water would boil at a temperature of 200° F.

Acids, bases, and salts.—These names have been given by chemists to certain classes of chemical compounds, the varieties of each class having a certain resemblance in properties and composition to the members of its own class. An understanding of the composition of acids, bases, and salts is highly desirable for those engaged in the search for minerals.

Acids are, usually, colourless liquid compounds, soluble in water. All acids contain hydrogen, combined either with an element or a group of elements; thus we have hydrochloric acid (HCl), nitric acid (HNO_3), sulphuric acid (H_2SO_4). When the contained hydrogen is replaced by a metal, the acid character disappears and a *salt* is formed. For example, by the action of hydrochloric acid on zinc (Zn), the hydrogen is replaced by the zinc, and chloride of zinc ($ZnCl$) is formed; or, again, H_2SO_4 acting upon barium (Ba) will result in barium sulphate ($BaSO_4$) being formed. The metal or metallic oxide replacing the hydrogen is known as a *base*.

The acids are seldom found free in nature, except in very small quantities, for they have in the majority of instances combined with bases with which they have come in contact, and have formed the group of bodies known as Salts—a group which is of the highest importance and value to man.

Nomenclature.—It will have been observed that in describing some of the chemical laws and properties above we have used in connection with the names of metals certain words, such as chloride, sulphide, oxide, sulphate, &c., and it will naturally be asked what these terms signify. These words

are used by chemists to denote the various conditions of composition of any compound substance, and by their aid we are enabled to correctly estimate the quantitative as well as the qualitative composition of all compound bodies.

In order to simplify this explanation, the names given to the compounds are arranged here in tabular form :—

Compounds of a base and		Oxygen	are termed	Oxides.
,,	,,	Sulphur	,,	Sulphides.
,,	,,	Arsenic	,,	Arsenides.
,,	,,	Chlorine	,,	Chlorides.
,,	,,	Bromine	,,	Bromides.
,,	,,	Iodine	,,	Iodides.
,,	,,	Fluorine	,,	Fluorides.
,,	Sulphides with	Oxygen	,,	Sulphates.
,,	Arsenides ,,	,,	,,	Arsenates.
,,	Chlorides ,,	,,	,,	Chlorates.
,,	Fluorine ,,	,,	,,	Fluorates.
,,	a Base, Oxygen, and	Carbon	,,	Carbonates.
,,	,, ,, ,,	Phosphorus	,,	Phosphates.
,,	,, ,, ,,	Nitrogen	,,	Nitrates.
,,	,, ,, ,,	Silicon	,,	Silicates.

There are many other compounds besides these, such as vanadates, tungstates, and some double compounds, such as sulph-arsenides and sulph-antimonides, but the chief names used, or rather those which will be found most useful to the readers for whom this book is intended, are included in the table given.

Oxygen and sulphur, among others, combine with many elements in more than one definite proportion, however, and a certain prefix to the word 'oxide' or 'sulphide' &c. expresses the exact amount of oxygen or sulphur with which the base is combined. Thus we have *mon*-oxide, *di*-oxide, *tri*-oxide, *tetra*-oxide, or *pent*-oxide, indicating that we have respectively, one, two, three, four, or five atoms of oxygen combined with the base. *Sesqui*-oxides have three atoms of oxygen combined with two atoms of a base.

Peroxide and *protoxide* are general terms used to imply either that a base is fully oxidised, or that it is in combination with a part only of the oxygen with which it is possible for it to combine.

Precipitation.—This term is one that is often used in

describing chemical reactions and the formation of various mineral deposits, and it is therefore desirable that we should understand its exact meaning. A substance is deposited or precipitated from a liquid when the quantity present exceeds the amount which the liquid can hold in solution. Thus, when sea-water is slowly evaporated the different salts in solution are in turn precipitated, as the saturation point for each is reached, the most insoluble being precipitated first, and the most soluble last.

Sometimes precipitation is brought about by chemical change, an insoluble compound having been formed in place of a soluble one. For example, nitrate of silver is readily soluble in water, but chloride of silver is practically insoluble; if a little common salt (NaCl) be added to a solution of nitrate of silver, the nitrate is immediately converted into a chloride of silver, which is precipitated as a white powder; or the reaction expressed in chemical symbols is thus:

$$\underbrace{AgNO_3}_{\text{Silver Nitrates}} + \underbrace{NaCl}_{\text{Sodium Chloride}} = \underbrace{AgCl}_{\text{Silver Chloride}} + \underbrace{NaNO_3}_{\text{Sodium Nitrate.}}$$

In the above, the sodium nitrate, being soluble, remains in solution in the water in which the experiment is carried out.

Decomposition is the term used to denote the splitting up of a compound into its elements or into two or more simpler compounds. The ordinary method of preparing quicklime (CaO) from limestone ($CaCO_3$) depends upon a process of decomposition; the limestone is heated in a kiln and is decomposed by the heat, the reaction taking place thus:

$$\underbrace{CaCO_3}_{\substack{\text{Calcium Carbonate}\\ \text{or}\\ \text{Limestone}}} = \underbrace{CaO}_{\substack{\text{Calcium Oxide}\\ \text{or}\\ \text{Quicklime}}} + \underbrace{CO_2}_{\text{Carbonic Acid Gas}}$$

The CO_2 passes away, of course, as gas.

Many metallic minerals when heated before the blowpipe are decomposed, the metallic constituent being the only visible residue of the experiment (see Section V., page 225).

From the above described laws and data it is believed that enough can be gleaned to enable the student to understand the various subjects dealt with hereafter.

CHAPTER II

Gaseous and Liquid Elements and Compounds

OXYGEN.

Symbol, O. *Atomic Weight*, 15·96.

Oxygen is a colourless invisible gas without taste or odour. It is a good supporter of combustion, any body which burns in the air burning in it with much greater brilliancy.

Occurrence.—Oxygen forms one-fifth, by bulk, of the atmosphere, and eight-ninths, by weight, of water. In combination, either as oxide, silicate, carbonate, nitrate, sulphate, phosphate, &c., it constitutes nearly half the entire weight of the solid crust of the globe.

HYDROGEN.

Symbol, H. *Atomic Weight*, 1.

Hydrogen is the lightest gas known; it is colourless and invisible, and burns in air with a non-luminous intensely hot flame. The process known as combustion consists of the combination of hydrogen with the oxygen of the air forming water-vapour (H_2O).

Occurrence.—It is found free in the gases evolved from some volcanic vents. In combination it occurs in water, of which it forms one-ninth part by weight; and it is an essential constituent of all acids.

WATER.

Symbol, H_2O. *Molecular Weight*, 17·96.

Water is a tasteless liquid of a faint blue colour, solidifying at a temperature of 32° F. and boiling at 212° F. It is the

most universal solvent known, there being few substances which are not to a greater or less extent soluble in water. All the fresh water upon the earth's surface has been derived by an immense process of distillation from the ocean. Rising as vapour from the sea, it has condensed as cloud matter above, from which it has fallen, in the form of hail, snow, sleet, or rain, back on to the earth. All the water thus falling finds its way ultimately to the sea, carrying with it large quantities of matter both in solution and suspension; the suspended matter gradually falls and settles upon the bed of the ocean, while much of the matter in solution is separated out by the agency of plants and animals (see Section IV. page 125), and their siliceous and calcareous skeletons form immense deposits beneath the sea.

Sea-water contains about 35 parts in every 1,000 of solid matter, 28 of which consist of common salt (NaCl).

Occurrence.—Water occurs in three forms in nature: solid, as ice, hail, or snow; liquid and gaseous, as water, vapour, or steam. In passing from the liquid to the solid state water increases in volume or bulk from 1 volume to 1·09 volume; this expansion exerts great force, capable of splitting even the hardest rocks (see Section IV., page 107).

Water expands and becomes lighter when cooled below a temperature of 39·2° F. At this temperature water is heaviest, and this point is therefore called the *maximum density-point of water*. Below this point, water, as we have said, expands, and instead of sinking remains floating on the surface until a temperature of 32° F. is reached, when the water begins to freeze. But as long as the freezing-point is not reached the light water on the top acts as a protecting coverlet for the warmer water below, which is thus saved from subsequent cooling and eventual freezing. This property of water is a most beneficial one to man, as it causes many lands which would become arctic in character to be fit for the habitation and progress of human life.

NITROGEN.

Symbol, N. *Atomic Weight*, 14·01.

Nitrogen is a colourless, tasteless, inodorous gas, rather lighter than air. It will not burn nor support combustion or animal life; it is not poisonous.

Occurrence.—Nitrogen occurs in the free state in the atmosphere, of which it constitutes about four-fifths by bulk. In combination it is found in the bodies of plants and animals, and also in various nitrates, and in many other chemical compounds, some of which, such as nitric acid (HNO_3), are of great commercial value.

THE ATMOSPHERE.

The atmosphere consists of a mechanical mixture, principally of the two gases oxygen and nitrogen. It is the gaseous envelope surrounding the entire earth, and is computed to be from 75 to 500 miles thick; we feel its movements when the wind blows or when we create a draught by running or riding or moving rapidly through it. The atmosphere exerts a pressure of about 15 lbs. per square inch upon everything exposed to it—our bodies, for example—but we do not feel the pressure, because it is equally distributed at the same rate all around and within us. In addition to the two gases mentioned we find aqueous vapour (H_2O), carbon dioxide (CO_2), and ammonia (NH_3) present in very small quantities in the atmosphere.

The aqueous vapour or moisture in the air varies at different times and in different localities; the higher the temperature of the air the greater the quantity of water it can hold as vapour.

When atmosphere saturated with moisture is cooled, the moisture is precipitated as mist, fog, or rain, or as hail and snow (see page 14). *Dew* is caused by the rapid cooling of the ground after sunset and before sunrise, which lowers the temperature of the air near the ground below the point at which it can retain all its moisture. At a temperature of

45° F. the atmosphere will contain about 10 grains of moisture in every cubic foot, but at 32° F. it will contain only about 2·4 grains in each cubic foot, the difference, 7·6 grains, being precipitated as rain &c.

Carbon dioxide only forms about 4 parts in every 10,000 of atmosphere; the falling moisture dissolves some of the carbon dioxide in the air, and its presence in water greatly increases the power of the latter to dissolve certain rocks (see Section IV., page 107); it also is instrumental in converting oxides into carbonates.

Ammonia occurs in still less quantities in the air, forming about 1 part in 1,000,000; it is the source from which plants derive the nitrogen which is necessary for the formation of their seeds and fruit.

In addition to the above there are greater or less quantities of various impurities in the air, the most important of which is floating organic matter, which is a certain cause of many diseases; malarial and camp fevers, so common in badly drained towns or low, marshy districts, are probably brought about by germs which have originated in organic matters in the tainted atmosphere.

Oxides of Nitrogen.

There are five compounds of oxygen and nitrogen known, as follows:—

1.	Nitrogen	monoxide (N_2O)	=	about	28	parts	by weight of	N	to 16	of O.
2.	„	dioxide (N_2O_2)	=	„	28	„	„	N	„ 32	„
3.	„	trioxide (N_2O_3)	=	„	28	„	„	N	„ 48	„
4.	„	tetroxide (N_2O_4)	=	„	28	„	„	N	„ 64	„
5.	„	pentoxide (N_2O_5)	=	„	28	„	„	N	„ 80	„

These oxides do not possess sufficient importance for us to require further notice, but some of their compounds possess considerable commercial value.

NITRIC ACID.

Symbol HNO_3. *Molecular Weight*, 62·89.

Nitric acid is a colourless liquid (that usually sold being of a pale-brown colour, owing to the partial decomposition of

oxides of nitrogen). It has a pungent odour, and possesses strong acid properties. It dissolves many metals, such as copper, silver, sodium, potassium, &c., and thus forms the group of compounds known as nitrates. Of the more important,

Sodium Nitrate ($NaNO_3$), having a molecular weight of 84·88, is commonly called Chili saltpetre. It is found in large beds in Chili and Peru, where it occurs as an incrustation many feet thick; and

Potassium Nitrate (KNO_3), having a molecular weight of 100·93. The potassium in this compound takes the place of the sodium in the last. It is called saltpetre, and is found in Russia and North America.

The former of these two is largely mined for manure.

AMMONIA.

Symbol, NH_3. *Molecular Weight,* 17·01.

This is the only compound of nitrogen and hydrogen. Ammonia gas is colourless, and has a most pungent smell, by which it can be readily recognised. It is exceedingly soluble in water, to which it imparts its peculiar odour.

Occurrence.—It is found in small quantities in the atmosphere (see page 16), and is formed in nature by the decomposition of animal and vegetable substances.

CARBON.

Symbol, C. *Atomic Weight,* 11·97.

This substance occurs in three native forms in nature: (1) diamond, (2) graphite, (3) charcoal. These differ much in all physical properties, but they each yield on combustion in oxygen the compound known as carbon dioxide (CO_2); they will be more fully dealt with in the section on mineralogy (see Section II., page 34).

Carbon is necessary for both plant and animal life, forming a part of all organised structures, and without it no life with which we are acquainted could exist.

Occurrence.—As carbon dioxide, in combination with

metallic oxides, it forms the important group of compounds known as Carbonates, of which the rock limestone is widely distributed over the earth's surface. Coal, which is a mineralised vegetation of great age, consists chiefly of carbon.

Compounds of Carbon and Oxygen.

Carbon Monoxide CO.
" Dioxide CO_2.

Carbon Monoxide.

Symbol, CO. *Molecular Weight*, 27·93.

Carbon monoxide is a colourless, inodorous gas which will not support combustion; it burns in the air with a pale blue flame, forming carbon dioxide. When breathed it acts as a violent poison.

Occurrence.—It occurs at some volcanic vents, and is a product of incomplete combustion. It is chiefly due to its presence, even in small quantity, that the 'choke-damp' of the miners derives its deadly properties; men brought up alive after an explosion of this gas in a coal mine frequently die afterwards from its poisonous effects.

Carbon Dioxide.

Symbol, CO_2. *Molecular Weight*, 43·89.

This compound is more commonly known as carbonic acid gas. It is a colourless, inodorous gas, with a slightly acid taste; it is somewhat soluble in water (see page 16), and is one of the chief products of ordinary combustion. It will not support life, but has no poisonous properties such as the monoxide.

Occurrence.—It occurs in a free state in the atmosphere (see page 16), at the bottom of old shafts and wells, and forms the greater part of the coal-miner's 'choke-damp.'

Compounds of Carbon and Hydrogen.

These compounds are very numerous in nature, existing as gases, liquids, and solids. The only one of the first class

with which we need here concern ourselves is marsh-gas, while in the two latter we have the valuable group of compounds known as Paraffines and their related species.

MARSH-GAS.

Symbol, CH_4. *Molecular Weight*, 15·97.

Marsh-gas, called also light carburetted hydrogen, is a colourless, tasteless, and inodorous gas. It burns with a bluish yellow non-luminous flame, forming carbon dioxide and water.

Occurrence.—When mixed with air it forms an explosive mixture, and constitutes the 'fire-damp' of the miners; the firing of an explosive mixture of this gas and air is the cause of so many disastrous explosions in coal-mines, where this gas commonly occurs.

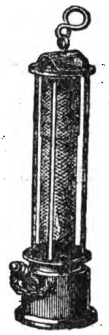

FIG. 3.—The Davy Safety Lamp.

To prevent the firing of this explosive mixture the Davy lamp, invented by Sir Humphry Davy, is commonly employed. It consists of an oil-lamp the upper part of which is completely enclosed by a very fine wire gauze; through this gauze the air can enter and the products of combustion escape, but, owing to the quick action of the wire gauze in conducting away the heat, the flame cannot pass from the inside to the outside of the lamp, so that ignition of the explosive gas cannot take place.

HALOGENS.

The elements forming this group have many varieties, but are only interesting to us in so far as they form metallic compounds, in which state they occur in considerable quantities upon the globe.

They are four in number, namely:

1. Chlorine.
2. Bromine.
3. Iodine.
4. Fluorine.

The more important of the compounds of these elements will be considered under Section II., on Mineralogy.

HYDROCHLORIC ACID.

Symbol, HCl. *Molecular Weight*, 36·37.

Hydrochloric acid is a colourless gas with a most pungent odour, exceedingly soluble in water, the aqueous solution being the acid of commerce.

Occurrence.—Hydrochloric acid is found free in nature in the gases evolved from some volcanoes; in combination with metals it forms the important group known as Chlorides (see page 10).

PHOSPHORIC ACID.

Symbol, H_3PO_4. *Molecular Weight*, 97·8.

This acid in combination with metals forms the group of compounds known as Phosphates, which are largely employed as manures; while others, such as pyromorphite (lead phosphate), are valuable metallic ores (see page 10).

SULPHURIC ACID.

Symbol, H_2SO_4. *Molecular Weight*, 97·82.

Sulphuric acid is a thick, oily, colourless liquid, often brownish from the presence of impurities. In combination with metals it forms the large and important group of minerals known as Sulphates (see page 10).

In this section we have touched lightly upon those chemical laws and data which are likely to be of service in the search for minerals; the various subjects have, of necessity, been but lightly reviewed, but sufficient has been written, it is believed, to enable the student or prospector to understand much which the latter at least generally regards as 'theory,' whereas it has an undoubted value and is of vital importance to a clear understanding of the following sections.

SECTION II

MINERALOGY

CHAPTER I

Physical Properties of Minerals

The study of the minerals of which the crust of the earth is formed constitutes the science of mineralogy. A mineral is a homogeneous substance, formed without the agency of man or the assistance of animal or vegetable life.

A few rocks, such as limestone and quartzite, consist of a single mineral in an impure state, but the majority of rocks consist of an aggregation of two or more minerals.

Gems are minerals which are used in jewellery, and ores are minerals that may be useful for man, on account of the metals which they may contain.

Water, the atmosphere, and the various gases that are ejected from volcanic vents are minerals, but owing to their nature they are not, as a rule, included in the study of mineralogy.

On the other hand, some bodies which are of a mineral or mineralised nature, such as coal, fossils, &c., although they have been formed indirectly through the agency of organic life, are classed and considered as minerals.

Physical Properties of Minerals.

Minerals possess certain physical properties which serve to distinguish them from one another; hence a careful study of this portion of the subject is of vital importance to those who wish readily and easily to distinguish mineral species.

The physical characteristics are all, with the exception of

taste and odour, dependent in a greater or lesser degree upon the form of their crystallisation.

They may be conveniently considered under the following divisions :—

1. Hardness.
2. Tenacity.
3. Specific Gravity.
4. Refraction, Polarisation.
5. Diaphaneity, Colour, and Lustre.
6. Electricity and Magnetism.

Hardness.

The hardness of different minerals varies greatly, and it is one of the first and most important tests which should be made by the student in determining a mineral. A scale of hardness has been prepared, and to this scale the hardness of all other minerals is referred. Commencing with the softest, and ending with the hardest, the scale is as follows :—

1.	Talc	is scratched by	
2.	Rock Salt	,,	,,
3.	Calcite	,,	,,
4.	Fluorite	,,	,,
5.	Apatite	,,	,,
6.	Orthoclase	,,	,,
7.	Quartz	,,	,,
8.	Topaz	,,	,,
9.	Sapphire	,,	,,
10.	Diamond		

The hardness of a mineral may be determined by drawing a file across an unweathered or unaltered portion, and noticing the sound and amount of powder produced, referring it then to a mineral in the scale; a good knife, too, will scratch any mineral of and below the hardness of orthoclase feldspar, and a little practice with one will enable the prospector to judge with sufficient accuracy the hardness of most of the minerals with which he may have to deal. A mineral having the same hardness as apatite is said to have the hardness 5, while one midway between apatite and fluorite is said to have a hard-

ness of 4·5. The above scale should be committed to memory, and constant practice should be made with a standard scale, as usually when hardness has to be determined in the field standard minerals are not accessible.

In crystals the hardness sometimes differs on the various facets, but where this is the case to any marked extent it will be mentioned in connection with the particular mineral.

Tenacity.

When a mineral breaks easily, or separates into coarse or fine powder on an attempt being made to scratch it, it is said to be *brittle*.

If a mineral can be hammered out into thin layers, as gold, silver, &c., it is said to be *malleable*.

If a mineral—like argentite, for example—can be readily split up into thin slices, it is said to be *sectile*.

Flexible minerals when bent remain in a bent position, but

Elastic minerals when bent spring back to their original position.

Specific Gravity.

The specific gravity of a mineral is its weight compared with an equal bulk of distilled water at a temperature of 60° F. If the mineral is twice as heavy as water, its specific gravity is 2; if ten times as heavy, it is said to be 10.

To obtain the specific gravity of a mineral it is first weighed in the ordinary manner with a delicate balance; the mineral is then suspended to one of the scales by a thread of silk and completely immersed in a vessel of distilled water (fig. 4), the weight being again taken. The *second* weight is subtracted from the *first*, the *remainder* being the amount of the loss by immersion, or the weight of a quantity of water equal in bulk to the mineral. By dividing this loss of weight *into* the *first* weight of the mineral in air the specific gravity is obtained.

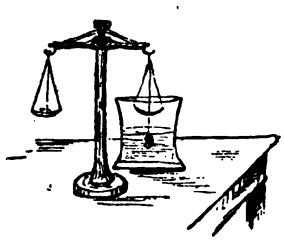

Fig. 4.

For example:

Mineral in air	4·5 oz.
,, water	3·2 oz.
Loss by immersion	1·3 oz.

Then $4·5 \div 1·3 = 3·46$, specific gravity of mineral.

Diaphaneity, Lustre, and Colour.

Diaphaneity is the property which many minerals possess of transmitting light, or of allowing light to pass through them. The following terms are used to express different degrees of this property:

Transparent when the outlines of objects seen through the mineral are distinct and clear.

Translucent when light is transmitted but objects cannot be seen.

Semi-transparent is a state of diaphaneity midway between the above two.

Opaque when no light is transmitted.

Lustre.

This property depends upon the nature of the surface of minerals. The different degrees of lustre are usually divided into the following six classes:

1. *Metallic*, the usual lustre of metals, such as gold, silver, copper, galena, &c. When the lustre is imperfect the mineral is said to be sub-metallic in lustre.

2. *Vitreous*, the lustre of broken glass, possessed in a marked degree by obsidian.

3. *Resinous*, like resin. Examples are zinc blende and amber.

4. *Pearly*, like pearls. Talc is a good example.

5. *Silky*, like silk, an appearance due to a very fine fibrous structure.

6. *Adamantine*, the lustre of the diamond. When a mineral is sufficiently adamantine in lustre to reflect images it is said to be *splendent*; when this is not so marked they are called *shining*. Minerals are said to *glisten* and *glimmer*

when there is a bright, scattered reflection from their surfaces.

Colour.

In using this property both the ordinary colour and the colour of the powder produced by scratching must be noted; for while the outward colour of a mineral varies greatly, the colour of the streak is nearly always the same.

The variety of colour found in the mineral world is well-nigh endless; we shall therefore mention the characteristic colour of each separate mineral in connection with it.

Play of colours is a term used when various prismatic colours appear as the mineral is turned about. The diamond and precious opal show a play of colours.

Change of colour, such as is seen in labradorite, sometimes occurs when a mineral is viewed from different directions.

Opalescent minerals have a milky or pearly appearance.

Phosphorescence is the property which some minerals possess of giving out light when gently rubbed or heated. Fluorite possesses this power in a marked degree.

Refraction and Polarisation.

The investigation of these properties requires a considerable quantity of expensive apparatus and an intimate knowledge of the laws of optics; it is therefore extremely unlikely that the prospector will be called upon to make use of these properties in the identification of minerals, so that mention of them is considered sufficient in this place.

Electricity and Magnetism.

Many minerals when rubbed become electrified and have the power of attracting light bodies; others when heated become electrical or pyro-electrical.

Magnetic properties are possessed to a great extent by the magnetic oxide of iron known as lodestone or magnetite; and some minerals, more especially those containing iron, nickel, and cobalt, are slightly attractable by the magnet.

Taste and Odour.

Taste can, of course, be only noticed in the soluble minerals. The various kinds of taste are thus classified :—

1. *Saline*	being the taste of		common salt.
2. *Alkaline*	,,	,,	soaps.
3. *Cooling*	,,	,,	peppermint.
4. *Astringent*	,,	,,	iron sulphate.
5. *Sweet-astringent*	,,	,,	alum.
6. *Sour*	,,	,,	unripe orange.
7. *Bitter*	,,	,,	gall.

Odour.

Odour is only to be detected in minerals in the majority of cases when they have been warmed by heat or friction. The different kinds of odour are usually classified thus :—

1. *Alliaceous*, a garlicky odour, characteristic of arsenic when heated.

2. *Horse-radish odour*, characteristic of selenium ores when heated.

3. *Sulphurous*, pungent and stifling, given off by many sulphides when heated.

4. *Fetid*, the smell of bad eggs, the odour of sulphuretted hydrogen, and sometimes given off by quartz and limestones when heated or rubbed.

5. *Argillaceous*, the odour of wet clay or damp earth, sometimes common in serpentine and olivine rocks.

Crystallisation.

Most inorganic bodies on their passage from a liquid to a solid state assume definite forms, which are known as *crystals*.

A bar of cast-iron is rough on the fractured surface, because of the angular crystalline grains which the molten iron assumes on cooling. A block of granite has an uneven surface, due to the different crystals of which it is composed.

A fully developed crystal may be defined as *a definite geometrical mass of mineral matter*.

A knowledge of the crystalline forms which minerals

assume will often be useful to the prospector in identifying them; for, although the forms are only imperfectly developed in many cases, instances will occur when crystals of the most perfect shape will be found, and it is by the careful study of such forms that the student will be enabled to identify the more imperfect examples.

The faces and forms of crystals are usually found in nature much distorted, owing to the juxtaposition and pressure of surrounding bodies; but with all such imperfections the angles of crystals remain the same in each class.

Axes of crystals.—These are imaginary lines intersecting one another at the centre of the crystals. They are imagined for the purpose of describing the position of the *facets* towards one another; and this position, as well as the length and number of the axes, determines the system to which a crystal rightly belongs.

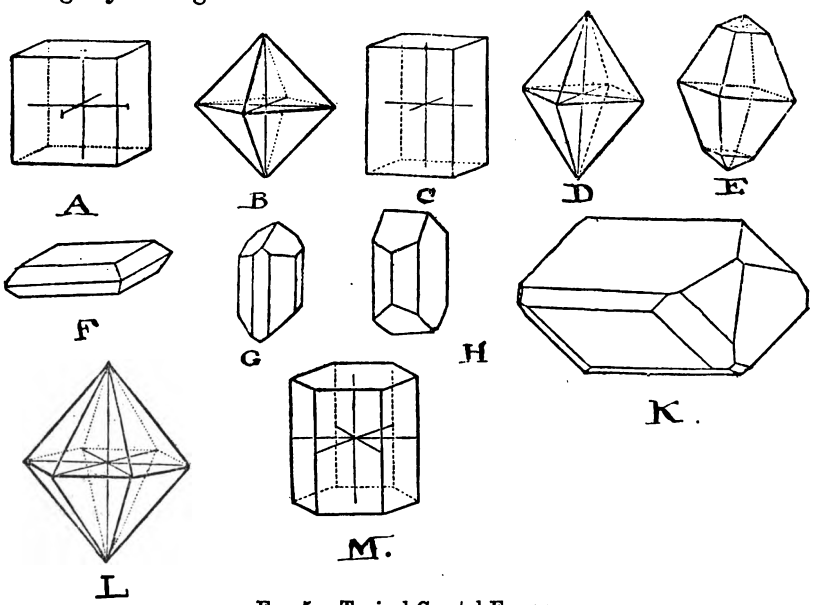

FIG. 5.—Typical Crystal Forms.

1. *Isometric system*; three axes, all of equal length, and all intersect one another at right angles (A and B, fig. 5).

2. *Tetragonal system*; three axes, two only of equal length,

the vertical axis being longer or shorter than the lateral ones; all intersect at right angles (C and D, fig. 5).

3. *Orthorhombic system*; three axes, all unequal in length but all intersect at right angles (E and F, fig. 5).

4. *Monoclinic system*; three axes, all unequal; two intersect at a right angle, the third is oblique (G and H, fig. 5).

5. *Triclinic system*; three axes, all unequal, and all intersect each other obliquely (K, fig. 5).

6. *Hexagonal system*; four axes, three being lateral and one vertical, which is either longer or shorter than the other three; the lateral axes intersect one another at an angle of 60° (L and M, fig. 5).

Cleavage is the property which most minerals have of splitting along certain planes. It is closely related to their crystalline form, and the direction in which they will split always bears a constant relation to the angle of their facets. The cleavage is generally easy in one direction only. Mica, fluorite, and galena are minerals with good cleavage, but quartz is a mineral which generally breaks only with an imperfect fracture. This property of *cleavage* must not be confounded with the cleavage of rocks, which is described under Section IV. (page 136), and which is produced by a totally different cause.

In addition to crystallisation forms, minerals assume many curious shapes; due, however, to the aggregation of crystals; some of the chief are described below.

1. *Acicular*, needle-shaped.

2. *Botryoidal*, like bunches of grapes.

3. *Columnar*, like columns or pillars.

4. *Concretionary*, in nodules, or round and oval lumps.

5. *Cryptocrystalline*, with a mere trace of crystalline structure.

6. *Crystalline*, crystalline structure without definite crystalline outlines.

7. *Dendritic or arborescent*, like fossil fern or leaf impressions.

8. *Capillary* or *Filiform*, like fine hairs.

9. *Granular*, in coarse, easily seen grains.

10. *Radiating*, when the crystals or fibres are arranged from a centre, like the spokes of a wheel.

11. *Reniform*, kidney-shaped.

12. *Reticulated*, like the meshes of a net.

13. *Scaly*, like fish-scales, or in easily separated plates.

14. *Stellate*, like stars.

15. *Tabular*, in broad flat plates or surfaces.

16. *Tuberous*, root-like.

A *pseudomorph* is a mineral which has a form other than that which naturally belongs to it. Pseudomorphs are produced by incrustation, by replacement, by infiltration, or by alteration. *Dimorphism* is the property possessed by some minerals of crystallising in two different systems; lime carbonate, for example, crystallises in the hexagonal form, as *calcite*, and in the orthorhombic form, as *aragonite*. Some minerals are *trimorphic*; that is to say, they are capable of crystallising in three different systems.

We will now endeavour to describe the chief minerals with which the prospector is likely to deal, and which he is most likely to find.

The classification adopted is that of that best of all mineralogists, James D. Dana, to whose manual of mineralogy we are indebted for much information which we have been unable to obtain from our own experience and collection of minerals; much has, of course, been left out, and many difficultly understood descriptions have been simplified, but those requiring further assistance are referred to the aforementioned work by Mr. Dana.

CHAPTER II

DESCRIPTION OF MINERALS [ACIDIC AND BASIC GROUPS]

MINERALS can be divided into the following classes:—

1. *The Acidic Group*, including the acid elements occurring in nature and their native compounds.

2. *The Basic Group*, including the native bases and their compounds, exclusive of silicates.

3. *The Silica Group*, including silica and the silicates.

4. *The Hydrocarbon Group*, including mineral oil, coals, and resins.

1. *Acidic Group.*

Subdivisions: A. Sulphur, tellurium, and molybdenum.
B. Boron.
C. Arsenic, antimony, bismuth.
D. Carbon.

2. *Basic Group.*

Gold, silver, platinum, iridium, palladium, quicksilver, copper, lead, zinc, tin, titanium, cobalt, nickel, uranium, iron, manganese, aluminium, magnesium, calcium, barium, strontium, potassium, sodium, ammonium.

3. *Silica Group.*

Subdivisions: E. Silica.
F. Anhydrous silicates.
(*a*) Bisilicates.
(*b*) Unisilicates.
(*c*) Subsilicates.
G. Hydrous silicates.
(*d*) General Section.
(*e*) Zeolite Section.
(*f*) Talc Section.

4. *Hydrocarbon Group.*

H. Oils, resins, wax.
J. Asphaltum, coals.

It will be seen from the above table that the more important minerals, as far as the prospector or miner is concerned, are those comprised in the second or Basic Group.

Some of these occur as native minerals, but for the most part they occur as oxides, sulphides, carbonates, phosphates, &c.

1. ACIDIC GROUP.

A. SULPHUR SUBDIVISION.

NATIVE SULPHUR.

Orthorhombic.[1]

Colour and streak.—Sulphur yellow, sometimes orange yellow.

Lustre.—Resinous. Translucent. Brittle.

H. = 1·5 to 2·5. *G.* = 2.

Burns with a blue flame and suffocating odour.

Dist.—By odour and flame.

Occ.—In beds of gypsum and near active and extinct volcanoes.

NATIVE TELLURIUM.

Hexagonal.

Colour and streak.—Tin white.

Lustre.—Metallic; opaque; brittle. *H.* = 2 to 2·5. *G.* = 6·25.

Dist.—On charcoal fuses and volatilises, tingeing the flame green.

Occ.—Uncommon; with gold, silver, and mercury forms tellurides.

MOLYBDENITE.

In thin plates like graphite, which it somewhat resembles.

Colour and streak.—Blue grey, streak sometimes greenish.

[1] In describing minerals, the form of crystallisation is first given. *H* stands for hardness; *G* for specific gravity; *Comp.* for chemical composition; *Dist.* for distinguishing features; and *Occ.* for the chief modes of occurrence.

Opaque.—*H.*=1 to 1·5. *G.*=4·5.

Dist.—Marks paper like graphite; gives off sulphur fumes when heated; soluble in nitric acid.

Occ.—In granite, gneiss, mica schist, granular limestone.

B. BORON SUBDIVISION.

SASSOLITE. BORACIC ACID.

In small white or yellow scales, feeling smooth and oily.

Taste.—Acid and a little salt and bitter.

H.=1. *G.*=1·5.

Dist.—Fuses easily in a candle-flame, turning it green.

Occ.—In the craters of volcanoes and in hot vapours from lagoons in Tuscany.

C. ARSENIC SUBDIVISION.

NATIVE ARSENIC.

Hexagonal, with imperfect cleavage.

Colour and streak.—Tin white, but usually tarnished grey.

H.=3·5. *G.*=5·75.

Dist.—Burns with a pale blue flame when heated just below redness, giving off white fumes. B. B. (before the blowpipe) volatilises readily before fusing, with odour of garlic.

Occ.—With silver and lead ores.

Orpiment. Yellow Arsenic Sulphide.

Orthorhombic, with perfect cleavage in one direction.

Comp.—As_2S_3. Sulphur 39 per cent., arsenic 61 per cent.

Colour and streak.—Fine yellow. Translucent. Sectile.

Lustre.—Brilliant pearly. *H.*=1·5 to 2. *G.*=3·5.

Dist.—Evaporates B. B. with garlic odour.

Realgar. Red Arsenic Sulphide.

Incrusting.

Comp.—AsS. Sulphur 29·9 per cent., arsenic 70·1 per cent.

Colour and streak.—Vermilion red; translucent.

H. = 1·5 to 2. *G.* = 3·5. *Dist.*—Like the preceding.

REMARKS.—The arsenic of commerce (As_2O_3), known as 'white arsenic,' is chiefly obtained from the roasted ores, tinstone and mispickel, the arsenic being driven off by heat in the form of a sesqui-oxide.

NATIVE ANTIMONY.

Hexagonal, but usually massive, with a distinct layer-like structure; sometimes granular.

Colour and streak.—Tin white. *H.* = 3 to 3·5. *G.* = 6·6.

Dist.—On charcoal B. B. fuses easily with dense white fumes.

Occ.—In veins of silver and other ores.

STIBUITE. ANTIMONITE.

Orthorhombic; columnar and fibrous; cleavage perfect in one direction; sometimes massive and granular.

Comp.—Sb_2S_3. Sulphur 28 per cent., antimony 72 per cent.

Colour and streak.—Lead grey, but tarnishes quickly.

H. = 2. *G.* = 4·5. Brittle; somewhat sectile.

Dist.—Fuses in a candle-flame, and B. B. passes off with white fumes and a sulphur odour.

Occ.—With ores of silver, lead, zinc, or iron in veins. Associated with quartz, barytes, or spathic iron.

From this mineral most of the antimony of commerce is obtained.

NATIVE BISMUTH.

Hexagonal, but generally massive, with distinct cleavage.

Colour and streak.—Silver white, slightly red. Tarnishes.

H. = 2 to 2·5. *G.* = 97·75. Brittle.

Dist.—B. B. on charcoal vaporises; leaves a yellow incrustation, which gets lighter on cooling.

Occ.—With ores of gold, silver, copper, and cobalt.

D. CARBON SUBDIVISION.

DIAMOND.

Isometric, faces often curved, cleavage perfect.

Comp.—Pure carbon.

Colour, white or colourless; also yellow, red, orange, green, blue, brown, and black.

Lustre.—Adamantine. Transparent to translucent when dark.

H.=10 (the hardest mineral known). *G.*=3·5.

Dist.—Burns only at a high temperature, when it froths up and turns black, producing CO_2 (carbon dioxide). Distinguished by its hardness, lustre, and brilliant reflection of light; will attract light bodies if electrified by rubbing.

Occ.—In alluvial sands and gravels in Brazil, Borneo, and India. At Kimberley, South Africa, in a volcanic rock (now known to be an olivine diabase with pikrite porphyry intrusions), filling up what are supposed to be the pipes of extinct volcanoes; also in alluvial sands and gravels in the Orange and Vaal rivers; at Yagersfontein, in the Orange Free State, diamonds of very good quality are found, as at Kimberley. Reported from Mozambique, Delagoa Bay, the Kalahari, and Basutoland.

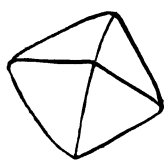

FIG. 6.

Diamonds are valued according to their colour (the best being white), transparency, and size. Black impure diamonds, unfit for jewellery, but useful for cutting and polishing, are called 'bort,' and in Brazil 'carbonado;' these sometimes occur in very large pieces.

GRAPHITE. PLUMBAGO. BLACK-LEAD.

Hexagonal, but usually massive and in leaves (foliated), sometimes granular.

Colour and streak.—Dark steel-grey to dull deep black.

Lustre.—Metallic. *H.*=1 to 2. *G.*=2·25.

Dist.—Completely infusible B. B. Not acted on by acids.

Looks like molybdenite, but is not so blue, and quite unaffected by the blowpipe. Feels greasy, and marks paper.

Occ.—Graphite is found in the older crystalline rocks, in gneiss, mica schist, and crystalline limestone. When pure and fine-grained, is very valuable if good ore bodies exist.

2. BASIC GROUP.

GOLD.

Isometric; without cleavage. Also in dendritic, filiform, and reticulated masses, in grains, plates, scales, and nuggets.

Comp.—Usually alloyed with silver, and sometimes with copper, platinum, and iron.

Colour and streak.—Gold yellow, paler when much silver is present; sometimes nearly silver-white. Malleable.

H.=2·5 to 3. *G.*=19 to 19·3 when pure, less when alloyed.

Dist.—Iron and copper pyrites and yellow mica are often mistaken for gold by the inexperienced, but the two former are brittle, while mica can be flaked off with a knife into thin flakes. Gold can be hammered out into thin sheets, and its high specific gravity tends also to distinguish it.

Occ.—In veins of quartz traversing highly tilted crystalline slates (see Section IV., page 161) in granyte, and hydromicaceous, and chloritic quartz rocks, in quartzytes and limestones. In South Africa it occurs in pyritous-siliceous conglomerates of probably Permian age. As nuggets, gold occurs in the sands and gravels of alluvial drift of existing drainage systems (shallow places), and in those of bygone system (deep leads). The nuggets have been apparently derived from parent auriferous lodes, and in some cases by precipitation. The gold at Witwatersrandt in the conglomerates aforementioned would appear to have been formed *in situ* by precipitation and condensation.

Tellurides of gold with other metals (calavarite, nagyagite, sylvanite) are of rare occurrence.

NATIVE SILVER.

Isometric; no cleavage. Often in filiform and dendritic shapes, the threads being crystalline; in grains and laminæ.

Comp.—Usually alloyed with gold and copper.

Colour and streak.—Shining silver-white. Tarnishes black.

H.=2·5 to 3. *G.*=10 to 11. Sectile. Malleable.

Dist.—Silver is distinguished by its malleability from bismuth and other white metals, and by the white precipitate obtained by adding salt to a solution of nitric acid containing silver. Is blackened by sulphuric acids. B. B. fuses easily to a silver globule.

Occ.—In association with native copper, and in strings and threads in many silver-ore bodies.

Argentite. Silver Glance.

Isometric; indistinct cleavage. Also massive and reticulated.

Comp.—Ag_2S. Silver 87 per cent., sulphur 13 per cent.

Colour and streak.—Blackish lead grey; streak shining.

H.=2 to 2·5. G.=7·25. Very sectile. *Lustre,* metallic.

Dist.—Argentite looks like some ores of copper and lead, but always gives a silver globule on charcoal B. B., with a sulphurous odour.

Occ.—In veins traversing the older geological systems.

Pyrargyrite. Ruby Silver.

Hexagonal.

Comp.—Ag_2S_3Sb. Sulphur 18 per cent., antimony 22 per cent., silver 60 per cent.

Colour and streak.—Black to bright rich red, streak rich red.

H.=2·25. *G.*=5·8. *Lustre.*—Metallic, splendent.

Dist.—By its red streak. On charcoal B. B. a white deposit of antimony oxide, and with soda a silver globule.

Occ.—In veins and lodes as above.

Proustite. Light Ruby Silver.

Like the last, but contains arsenic in place of antimony. B. B. gives a garlic odour.

Stephanite.

Orthorhombic. Often in compound crystals.

Comp.—Ag_5S_4Sb. Sulphur 16 per cent., antimony 16 per cent., silver 68 per cent.

Colour and streak.—Iron black.

H.=2 to 2·5. *G.*=6·25.

Dist.—Soluble in nitric acid. B. B. sulphur fumes; a deposit of antimony oxide on charcoal.

Occ.—As with previous silver ores.

Cerargyrite. Horn Silver.

Isometric. Also massive and in laminæ.

Comp.—AgCl. Chlorine 25 per cent., silver 75 per cent.

Colour and streak.—Grey, green, blue; streak shining.

H.=1·25. *G.*=5·3 to 5·5.

Dist.—Looks and cuts like horn; fuses in a candle-flame. B. B. gives silver on charcoal easily; rubbed on a plate of iron gives a silvered surface.

Occ.—A valuable and common ore found in connection with copper and lead ores in the older stratified and crystalline rocks.

Bromides and iodides of silver are also found usually associated with the above silver ores.

NATIVE PLATINUM.

Isometric, but crystals rare. Usually in angular grains and flattened lumps.

Comp.—Usually alloyed with its related minerals, iridium, rhodium, osmium, and palladium.

Colour and streak.—Dark steel-grey.

Lustre.—Metallic, shining.

H.=4 to 4·5. *G.*=16 to 19, and when pure 21·5. Malleable.

Dist.—Platinum is easily distinguished by its extreme infusibility, by its high specific gravity, and its malleability.

Occ.—Found in alluvial sands and gravels in fine grains; sometimes also in largish masses. It comes chiefly from Russia.

NATIVE MERCURY. QUICKSILVER.

Isometric; in fluid globules scattered through the gangue.

Colour.—Tin white. $G.=13{\cdot}58$.

Dist.—It is completely volatile B. B., and dissolves in nitric acid. Its fluidity also distinguishes it.

Occ.—Found with cinnabar, and also in shales of a dark black colour; sometimes in alluvial sands as fluid globules.

Cinnabar. Mercury Sulphide.

Hexagonal; cleavage in one direction perfect; sometimes massive and incrusting.

Comp.—HgS_2. Sulphur 14 per cent., mercury 86 per cent.

Colour and streak.—Ruby red and brown. Subtransparent to opaque.

$H.=2$ to $2{\cdot}5$. $G.=9$ when pure. Sectile.

Dist.—Distinguished from iron oxide and lead chromate by evaporating B. B. Realgar, something like cinnabar; gives off garlic-smelling fumes.

Occ.—Found chiefly near hydromica slates, and in connection with hornblendes and asbestos rocks, or in sandstones near these.

Cinnabar is the ore from which most of the mercury of commerce is obtained.

NATIVE COPPER.

Isometric; often much distorted. Also in plates and masses, and in thread-like and dendritic forms.

Colour and streak.—Copper red.

$H.=2{\cdot}5$ to 3. $G.=8{\cdot}9$. Malleable.

Dist.—B. B. fuses readily, and on cooling becomes covered with black oxide. Dissolves in nitric acid, and produces a deep rich blue colour when ammonia is added.

Occ.—Found near dykes and intrusive veins in Cambrian rocks, and near porphyryte; frequently accompanies copper ores.

Chalcocite. Copper Glance.

Orthorhombic. Often massive.

Comp.—Cu_2S. Sulphur 20 per cent., copper 80 per cent.

Colour and streak.—Blackish lead grey; often tarnished blue or green.

H.=2·5 to 3. *G.*=5·75.

Dist.—Looks like argentite, but B. B. gives off sulphurous fumes, and leaves a bead of copper on charcoal.

Occ.—Found with other copper ores in Cambrian slates, and in schorl granyte near tin ores.

Chalcopyrite. Copper Pyrites.

Tetragonal. Also massive. Indistinct cleavage.

Comp.—$CuFeS_2$. Sulphur 35 per cent., copper 35 per cent., iron 30 per cent.

Colour and streak.—Brass yellow or iridescent (rainbow colours). Streak unmetallic, greenish black, dull.

H.=3·75. *G.*=4·25.

Dist.—Looks like gold and iron pyrites. Is to be distinguished from the former by its streak, and from the latter by being readily scratched with a knife.

Occ.—Found in veins in Cambrian slates, near porphyryte and gneiss; near greenstone rocks. Associated with iron pyrites and malachite.

Generally a poor ore of copper.

Bornite. Erubescite. Variegated Copper.

Isometric. Also found massive.

Comp.—Cu_2FeS_2. Sulphur 30 per cent., copper 56 per cent., iron 14 per cent.

Colour and streak.—Copper red and many-coloured; tarnishes quickly; streak slightly shining, pale grey.

H.=3. *G.*=4·4 to 5·5. Brittle.

Dist.—B. B. on charcoal fuses to a brittle globule, which is attractable by the magnet.

Occ.—Found with other copper ores.

Tetrahedrite. Grey Copper. Fahlerz.

Isometric.

Comp.—$4CuS + Sb_2S_3$. With iron, zinc, silver, and mercury sometimes.

Colour and streak.—Steel grey to blackish; streak often brown to brownish red.

H.=4. *G.*=4·75.

Dist.—From other copper ores by the fumes of antimony B. B., and by the hardness.

Occ.—In mineralised geyser-pipes, and generally in association with other copper ores.

Atacamite. Copper Oxichloride.

Orthorhombic. In clustered crystals.

Comp.—Chlorine 17 per cent., oxygen 11 per cent., copper 60 per cent., water 12 per cent.

Colour and streak.—Beautiful dark green, with a lighter streak.

H.=3 to 3·5. *G.*=3·8. *Lustre.*—Adamantine.

Dist.—By its brilliant lustre, and the presence of a large quantity of water, which can be vaporised and condensed in a test-tube.

Occ.—Very rare in large masses, but is associated with most copper ores in small quantities.

Cuprite. Copper Oxide.

Isometric. Also massive, and sometimes earthy.

Comp.—Cu_2O. Oxygen 11 per cent., copper 89 per cent.

Colour and streak.—Deep red; streak brownish red.

Lustre.—Adamantine or sub-metallic.

H.=3·5 to 4. *G.*=6. Brittle. Subtransparent.

Dist.—From cinnabar by not being volatile B. B., and from hematite by giving a copper bead on charcoal.

Occ.—Found with other copper ores in Cambrian slates, and near volcanic granyte.

A valuable copper ore.

Chalcanthite. Blue Vitriol. Copper Sulphate.

A rich sky-blue mineral, easily soluble in water, and is not found in quantity in nature. It is found in the water of copper mines, from which the contained copper is precipitated on to iron.

Comp.—$CuSO_4$ + water. Copper 32 per cent., sulphuric acid 32 per cent., water 36 per cent.

Dist.—It can be distinguished by dipping a clean knife, screw, nail &c. into it, when the copper will be precipitated, like red mud, upon the iron.

Malachite. Green Copper Carbonate.

Monoclinic. Usually in incrustations, with a smooth botryoidal surface. Also fibrous and earthy.

Comp.—$CuCO_3$ + water. Carbon dioxide 20 per cent., copper oxide 72 per cent., water 8 per cent.

Colour and streak.—Light green; streak paler.

Lustre.—Adamantine to vitreous for crystals.

H. = 3·5 to 4. *G.* = 3·75.

Dist.—Easily told by its marble-like, pale green colouring, and by effervescing in acids, which turquoise, which it somewhat resembles, will not do.

Occ.—Found with other copper ores, often incrusting them; and lining cavities in copper lodes.

Azurite. Blue Copper Carbonate.

A brittle ore, of the same composition as the last, but with less water and a bright blue colour.

Chrysocolla. Hydrous Copper Silicate.

Incrusting; botryoidal and massive, and in thin seams.

Comp.—$CuSiO_3$ + water. Silica 34 per cent., copper oxide 45 per cent., water 21 per cent.

Colour and streak.—Clear blue-green. *Lustre.*—Shining.

H. = 3. *G.* = 2 to 2·4.

Dist.—Not so compact as malachite; rather softer, and will not effervesce in acid.

Occ.—With other copper ores. A valuable ore if pure and in bulk.

LEAD.

Native lead is said to have been seen in the lava of the island of Madeira.

Galena. Lead Sulphide.

Isometric; with magnificently developed cleavage. Also granular.

Comp.—PbS. Sulphur 13·5 per cent., lead 86·5 per cent.

Colour and streak.—Lead grey. *Lustre.*—Metallic.

H.=2·5. *G.*=7·25. Fragile, brittle.

Dist.—It can be easily distinguished by its ready cleavage and its softness. B. B. on charcoal gives a globule of lead which is malleable, a sulphur odour, and leaves a yellow coating on the charcoal.

Occ.—Found associated with zinc, copper, and silver ores; in veins in granyte, limestone, and old sandstone rocks; for gangues it has chiefly calcite and barytes, but quartz and fluorite are not uncommon. Galena is often a gangue of silver, which latter may pay for extraction; that occurring in crystalline metamorphic rocks is most likely to be silver-bearing.

Minium. Oxide of Lead.

Pulverulent (easily powdered).

Comp.—Pb_3O_4. Oxygen 10 per cent., lead 90 per cent.

G.=4·5.

Dist.—Somewhat like cinnabar and realgar, but B. B. in the reducing flame yields lead globules.

Occ.—Found with galena and cerussite, and also with the zinc ore Smithsonite.

Anglesite. Lead Sulphate.

Orthorhombic, with distinct cleavage. Also massive and granular.

Lustre.—Adamantine to resinous.

Comp. $PbSO_4$. Oxygen 21 per cent., sulphur 11 per cent., lead 68 per cent.

Colour and streak.—White to grey and green; streak white.

H.=2·75 to 3. *G.*=6·4. Brittle.

Dist.—Readily fuses in a candle-flame. B. B. on charcoal, with soda, gives a bead of lead. Also distinguished by its high specific gravity.

Occ.—It is merely the result of decomposition of galena, with which it is found.

Crocoisite. Lead Chromate.

Monoclinic. Also massive.

Comp.—$PbCrO_4$. Chromium trioxide 31 per cent., lead oxide 69 per cent.

Colour and streak.—Bright red; streak yellow.

H.=2·5 to 3. *G.*=6.

Dist.—B. B. blackens, forms a slag with lead globules in it.

Occ.—A rare mineral; used chiefly as a paint known as chrome yellow; associated with other copper ores.

Pyromorphite. Lead Phosphate.

Hexagonal; also globular and kidney-shaped.

Comp.—Phosphorus pentoxide 15·75 per cent., lead oxide 82·25 per cent., chlorine 2 per cent.

Colour and streak.—Light olive green to yellowish; streak nearly white.

Lustre.—Resinous. *H.*=3·75. *G.*=7. Brittle.

Dist.—B. B. fuses easily, colouring flame bluish green.

Occ.—An unimportant mineral found in some lead-mines.

Cerussite. Lead Carbonate.

Orthorhombic; often in compound crystals.

Comp.—$PbCO_3$. Carbon dioxide 16·5 per cent., lead oxide 83·5 per cent.

Colour and streak.—White and greyish.

Lustre.—Adamantine. *H.*=3·25. *G.*=6·47. Brittle.

Dist.—Dissolves with effervescence in nitric acid. Also known by its high specific gravity and by yielding a bead of lead B. B.

Occ.—Found in limestones and siliceous sandstones; usually associated with galena and other lead ores.

NATIVE ZINC.

Native zinc is exceedingly rare.

Sphalerite. Blende. Zinc Sulphide.

Isometric, with good cleavage. Also found massive.

Comp.—ZnS. Sulphur 33 per cent., zinc 67 per cent.

Colour and streak.—Wax-yellow brown to resin brown, white. Streak whitish yellow to reddish brown.

Lustre.—Distinctly resinous. Subtransparent.

H.=3·5 to 4. *G.*=4. Brittle.

Dist.—This ore is characterised by its lustre, cleavage, and by being nearly infusible. Dissolves in nitric acid with a fetid odour.

Occ.—In rocks of all the older geological systems, and often associated with lead ores; sometimes with sulphur, iron, and tin ores. A useful ore.

Calamine. Zinc Carbonate.

Hexagonal, with perfect cleavage. Also in masses and in reniform and stalactitic forms.

Comp.—$ZnCO_3$. Carbon dioxide 35 per cent., zinc 65 per cent.

Colour and streak.—Nearly white, sometimes green or pale brown.

Lustre.—Vitreous and pearly. *H.*=5. *G.*=4·4. Brittle.

Dist.—This mineral effervesces freely in acid. Its hardness and fumes of zinc emitted B. B. distinguish it from other carbonates.

Occ.—Chiefly in limestones and with galena or blende.

Hemimorphite. Hydrous Zinc Silicate.

Orthorhombic, with perfect cleavage; generally incrusting and stalactitic.

Comp.—Zn_2SiO_4 + water. Silica 25 per cent., zinc oxide 67 per cent., water 8 per cent.

Colour and streak.—White and pale shades of blue and green.

H.=4·75. *G.*=3·2 to 3·9.

Dist.—Dissolves in sulphuric acid, forming a jelly when cool. B. B. infusible.

Occ.—Chiefly with galena and zinc ores. It is a valuable ore of zinc.

TIN. STANNITE. TIN PYRITES.

Usually massive or in grains.

Comp.—Sulphur 30 per cent., tin 27 per cent., copper 30 per cent., iron 13 per cent.

Colour and streak.—Steel grey to iron black; streak black.

Lustre.—Metallic. *H.*=4. *G.*=4·5. Brittle.

Dist.—Characterised by its B. B. reactions for tin, copper, and iron, and by its specific gravity from platinum.

Occ.—Found in schorl-granyte and with cassiterite.

Cassiterite. Tin Oxide.

Tetragonal. Also in masses and grains.

Comp.—SnO_2. Oxygen 21 per cent., tin 79 per cent.

Colour and streak.—Brown, black, yellow; streak pale grey to brownish.

Lustre.—Adamantine. *H.*=6 to 7. *G.*=6·5 to 7.

Dist.—B. B. on charcoal with soda yields a globule of tin. Is harder than blende, which it looks like.

Occ.—In schorl granites, near slates; in quartz-ore gneiss and mica schist; it is frequently associated with wolfram, iron, topaz, and tourmaline. Cassiterite is the chief ore of tin, but is very sparsely distributed. 'Stream-tin' is found in alluvial sands and gravels, as detrital matter from tinstone veins.

TITANIUM.

Titanium does not occur native. Its chief ore is rutile (TiO_2). It is a brownish red mineral with an adamantine lustre and pale brown streak.

H.=6 to 6·5. *G.*=4·2.

Dist.—B. B. unaltered. Splinters of a light red colour are distinguishing features.

Occ.—In granite, gneiss, granular limestone, and quartz.

COBALT AND NICKEL.

The compounds of these associated minerals are many, but of them all the following are the more common.

Cobaltite.

Isometric.

Comp.—CoAsS. Arsenic 45 per cent., sulphur 19 per cent., cobalt 36 per cent.

Colour and streak.—Silver white with a tinge of red; streak greyish black.

H.=5·5. *G.*=6·25. Brittle.

Dist.—Unlike smaltite, gives sulphur fumes when heated. Differs from mispickel by giving a blue bead with borax.

Occ.—Found in slates of silurian age near to granites; frequently associated with copper and tin ores.

Smaltite. Cobalt Glance.

Isometric. Also reticulated and massive.

Comp.—$CoNiAs_2$. The amount of nickel varies, and is often very small.

Colour and streak.—Tin white; streak greyish black.

H.=5·5 to 6. *G.*=6·5 to 7. Brittle, with uneven fracture.

Dist.—It resembles mispickel, but the latter is distinguished by giving off both sulphur and arsenic fumes when heated.

Occ.—As in the last, but more frequently found.

Earthy Cobalt.

Massive. *Colour.*—Black or blue black.

Occ.—With wad, or bog manganese, in an earthy form.

Erythite. Cobalt Bloom.

Monoclinic, with perfect cleavage. Also incrusting.

Comp.—$CO_3(AsO_4)_2$ + water. Contains 38 per cent. of cobalt oxide.

Colour and streak.—Peach or crimson red; streak paler.

H.=1·5 to 2. *G.*=2·95.

Dist.—Resembles red antimony, but does not volatilise entirely B. B. Gives a blue bead with borax.

Occ.—Frequently found incrusting cavities in other ores of cobalt, and associated with copper and tin.

Kupfernickel. Niccolite.

Hexagonal, but generally massive.

Comp.—NiAs. Nickel 44 per cent., arsenic 56 per cent.

Colour and streak.—Pale copper-red; streak paler.

Lustre.—Metallic. *H.*=5 to 5·5. *G.*=7·5. Brittle.

Dist.—By its colour and the arsenical fumes given off on charcoal B. B. Gives a characteristic sherry-coloured bead with borax.

Occ.—Found accompanying ores of silver, copper, and cobalt; in granyte and crystalline slates.

Emerald Nickel. Nickel Carbonate.

In minute globules. Incrusting. Stalactitic.

Comp.—$NiCO_3$ + water. *Colour.*—Bright emerald green.

H.=3 to 3·25. *G.*=2·6.

Dist.—B. B. gives off water and loses its colour.

Occ.—A rare mineral, occurring in olivine rocks.

URANIUM.

Pitchblende. Uranium Oxide.

Isometric. Also massive and botryoidal.

Comp.—U_3O_4. Uranium 79 per cent., oxygen 21 per cent.

Colour and streak.—Greyish velvet black; streak velvety.

Lustre.—Submetallic.

H.=5·5. *G.*=9.25. Lower when impure.

Dist.—B. B. infusible. With borax gives a yellowish green bead. Also distinguished by its high specific gravity.

Occ.—Occurs with lead and silver ores, and has been found in Cornwall in association with tinstone.

Uranite. Uranium Mica.

Tetragonal. In square tables which split into thin leaves.

Comp.—A uranium and copper phosphate.

Colour.—Various shades of green, with streak a little lighter.

Lustre.—Pearly. *H.*=2 to 2·5. *G.*=3·5.

Dist.—Its bright green colours, the shape of the crystals, and their perfect cleavage, are readily noticed features.

Occ.—With other uranium and tin ores in slates and granyte.

IRON.

Native Iron.

Isometric.

Colour and streak.—Iron grey; fracture uneven.

Lustre.—Metallic.

H.=4·5. *G.*=7·5. Malleable and magnetic.

Occ.—Native iron is of rare occurrence; it occurs in grains in some igneous rocks, and forms the chief constituent of most meteorites.

Iron Pyrites. Pyrite.

Isometric; usually in cubes. Also massive.

Comp.—FeS_2. Sulphur 53 per cent., iron 47 per cent.

Lustre.—Metallic. *H.*=6 to 6·5. *G.*=4·8 to 5. Brittle.

Dist.—It is distinguished from copper pyrites by its being much harder and paler in colour.

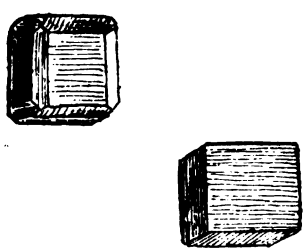

Fig. 7.

Occ.—Pyrites occurs in rocks of all ages, both igneous and sedimentary, and, owing to its tendency to decompose, it is the cause of disintegration of rocks to a large extent. It is an inferior iron ore, but the sulphur it contains is used in the manufacture of sulphuric acid. Pyrites in quartz is frequently auriferous, but it is doubtful if the gold has such an affinity to the iron as it has to the silica of the rocks.

Marcasite. White Pyrites.

Orthorhombic. This ore resembles pyrites in appearance and composition, being rather paler, however. It is frequently found in the core of twigs and branches in lignite.

Pyrrhotite. Magnetic Pyrites.

Hexagonal; but generally massive.

Comp.—Fe_7S_8. Sulphur 39·5 per cent., iron 60·5 per cent. It often contains nickel, and may be valuable as an ore of that metal.

Colour and streak.—Bronze yellow to copper red; streak greyish black.

H.=3·5 to 4·5. *G.*=4·5. Brittle.

Dist.—It is slightly magnetic and tarnishes rapidly. It might be mistaken for pyrite or marcasite, but it is darker and softer.

Occ.—As for the two preceding, but less frequent.

Mispickel. Arsenical Iron Pyrites.

Orthorhombic.

Comp.—FeAsS. Iron 34·5 per cent., arsenic 46 per cent., sulphur 19·5 per cent.

Colour and streak.—Silver white; streak greyish black.

Lustre.—Shining. *H.*=5·5 to 6. *G.*=5·75. Brittle.

Dist.—B. B. gives off arsenic fumes and a magnetic globule. Arsenical cobalt is much softer.

Occ.—Found in crystalline rocks, and is a common associate of gold, silver, lead, iron, and copper.

Hematite. Specular Iron Ore.

Hexagonal; often massive, granular, and fibrous; sometimes micaceous. Pulverulent also.

Comp.—Fe_2O_3. Iron 70 per cent., oxygen 30 per cent.

Colour and streak.—Dark steel grey or iron black with a reddish tinge; streak cherry red.

Lustre.—Of crystals, splendent.

H.=4·5 to 5. *G.*=5·5 to 6·5.

Dist.—Its red powder and magnetic properties (after being strongly heated) are distinguishing features.

Occ.—Found in various forms and stages of decomposition in rocks of all ages, igneous, crystalline, and stratified. Often occurs in large masses, and is a valuable ore of iron. *Red*

ochre and *red chalk* are impure clay varieties, and *jaspery clay iron* is a hard crystalline banded form.

Ilmenite. Titanic Iron.

Hexagonal.

Comp.—Same as for hematite, but contains titanium in place of some of the iron.

Colour and streak.—Iron black.

Lustre.—Metallic to submetallic.

H.=5 to 6. *G.*=4·5 to 5.

Dist.—Resembles hematite, but does not give a red streak.

Occ.—Found in iron ores. It is of no use in the arts.

Magnetite. Lodestone.

Isometric; also massive.

Comp.—Fe_3O_4. Oxygen 28 per cent., iron 72 per cent.

Colour and streak.—Iron black.

H.=5·5 to 6·5. G.=5. Brittle.

Dist.—Its strong magnetism, black streak, and infusibility B. B. are readily recognised features.

Occ.—Found in disseminated crystals in volcanic rocks; also massive, often forming mountains; in granyte, gneiss, clay slate, mica schist, &c.; also in limestone.

The most valuable ore of iron.

Fraulinite.

Isometric; also massive and granular.

Comp.—Like magnetite, but some of the iron replaced by manganese and zinc.

Colour and streak.—Iron black; streak reddish, brownish.

H.=5·5 to 6·5. *G.*=4·5 to 5. Brittle.

Dist.—Resembles magnetite, but B. B. gives a zinc incrustation. Streak, too, is different.

Occ.—Associated with red zinc oxide.

Chromite. Chromic Iron.

Isometric; usually massive, with dull rough fracture.

Comp.—Same as magnetite, but with part of the iron replaced by chromium.

Lustre.—Dull.

Colour and streak.—Brownish-black or brown.

H.=5·5. *G.*=4·5.

Dist.—B. B. infusible; with borax gives a green bead; its absence of lustre distinguishes it from other black iron ores.

Occ.—Usually in imbedded veins or masses in serpentine or olivine rocks; also in disseminated crystals.

Limonite. Brown Hematite.

Usually massive; often botryoidal or stalactitic, with a compact fibrous structure. Earthy also.

Comp.—Fe_2O_3 + water. Iron sesquioxide 86 per cent., water 14 per cent.

Colour and streak.—Dark brown to chrome yellow; streak same.

Lustre.—Submetallic, dull, earthy, or silky, according to structure.

H.=5 to 5·5. *G.*=3·75.

Dist.—Gives off water B. B. and blackens and becomes magnetic.

Occ.—Found in rocks of all ages; derived from the decomposition of other iron-bearing minerals. A valuable iron ore, largely employed in the arts.

Melanterite. Copperas. Iron Vitriol.

Monoclinic; usually incrusting.

Comp.—$FeSO_4$ + water. Sulphur trioxide 29 per cent., iron protoxide 26 per cent., water 45 per cent.

Colour and streak.—Bluish-green; streak lighter.

Lustre.—Vitreous. *Taste.*—Astringent.

H.=2. *G.*=1·8. Brittle.

Dist.—Its taste and colour serve to distinguish it.

Occ.—Occurs in mines of pyrites, pyrrhotite, or marcasite, from which it has resulted by oxidation.

Wolframite.

Monoclinic; also massive.

Comp.—(FeO and MnO) + WO_3. Tungsten trioxide 76·5

per cent., iron protoxide 9·5 per cent., manganese protoxide 14 per cent.

Colour and streak.—Dark greyish black; streak reddish brown.

Lustre.—Submetallic, shiny. *H.*=5·5. *G.*=7·0 to 7·5.

Dist.—Dissolves in aqua regia, with separation of yellow tungsten oxide. B. B. fuses to a magnetic globule.

Occ.—Usually found associated with tin ores.

Vivianite. Hydrous Iron Phosphate.

Monoclinic, perfect cleavage. Also incrusting.

Comp.—Phosphorus pentoxide 28 per cent., iron protoxide 43 per cent., water 29 per cent.

Colour and streak.—Deep blue to greenish; streak bluish-green.

Lustre.—Pearly to vitreous. Transparent to translucent.

H.=1·5 to 2. *G.*=2·65.

Dist.—Dissolves in hydrochloric acid; gives off water when heated in a closed tube; its colour and softness are distinguishing features. Colours blowpipe flame pale greenish blue.

Occ.—Found with bog iron ore, and sometimes in clay; associated with iron, copper, and tin ores.

Siderite. Chalybite. Iron Carbonate.

Hexagonal; cleavage good, faces often curved. Usually massive, with foliated structure.

Fig. 8.

Comp.—$FeCO_3$. Carbon dioxide 38 per cent., iron protoxide 62 per cent. Often contains some manganese.

Colour and streak.—Greyish white to brown and red; turns nearly black on exposure.

H.=3 to 4·5. *G.*=3·8. *Lustre.*—Pearly.

Dist.—Dissolves in hot hydrochloric acid with efferves- . B. yields a magnetic globule.

Occ.—Occurs in deposits in veins in gneiss, mica schist, and limestone; it occurs in the coal formations in impure nodules in beds of argillaceous character. It is a valuable iron ore.

MANGANESE.

Pyrolusite. Black Oxide of Manganese.

Orthorhombic; also massive, reniform, and fibrous.

Comp.—MnO_2. Manganese 63 per cent., oxygen 37 per cent.

Colour and streak.—Iron black, dull.

H.=2 to 2·5. *G.*=4·8.

Dist.—Gives a beautiful amethyst bead in borax B. B.

Occ.—In many of the older geological formations; a common associate of iron.

Psilomelane.

The same as the preceding, but occurs massive.

Colour.—Dull dead-black. *Streak.*—Reddish, shining.

H.=5 to 6. *G.*=4 to 4·5.

Contains a little potassium, barium, and always water.

Wad. Bogmanganese.

Earthy; in coatings and dendritic markings on joints of rocks.

Comp.—Manganese dioxide with iron and water.

Colour and streak.—Black or brownish-black.

H.=1 to 6. *G.*=3 to 4.

Dist.—Soils the fingers; gives off water when heated. It is used as a paint, and results from the decomposition of manganese ores.

Occ.—In low-lying marshy places. Also in the joints of rocks, as is shown in fig. 9. It is a common associate with gold-bearing quartz.

Fig. 9.

Mallardite.

A hydrous manganese sulphate.

Comp.—$MnSO_4$ + water. Rare.

Triphyllite.

Orthorhombic.

Comp.—Phosphorus pentoxide 44·19 per cent., iron protoxide 38·21 per cent., manganese protoxide 5·63 per cent., with small quantities of lime, soda, potash, lithia, magnesia, and silica.

Colour and streak.—Green or blue grey; streak whitish.

Lustre.—Subresinous. *H.*=5. *G.*=3·5.

Dist.—Fuses easily; colours flame of blowpipe red with a green centre.

Occ.—In slates and other old rocks of primary age; accompanying iron ores.

Triplite.

Orthorhombic. Usually massive; cleavage in three directions.

Comp.—A manganese fluor-phosphate.

Colour.—Blackish. *Streak.*—Yellowish.

H.=5 to 5·5. *G.*=3 to 4.

Dist.—Dissolves in hydrochloric acid; imparts a rich violet colour to hot borax bead, which turns brown on cooling.

Occ.—With manganese and iron ores.

Rhodochrosite. Manganese Carbonate.

$MnCO_3$. Manganese oxide 61 per cent. Carbonic acid 39 per cent.

An unimportant rose-coloured ore. *G.*=3·5.

ALUMINIUM.

Sapphire Corundum. Aluminium Oxide.

Rhombohedral, with good cleavage. Also massive and earthy.

Comp.—AlO_2. Oxygen 46·8 per cent., aluminium 53·2 per cent.

Colours.—Blue, red, yellow, and brown, with various impure stages.

Lustre.—Of crystals adamantine, glimmering, splendent. Transparent to opaque for the impure varieties.

H.=9. *G.*=4. Tough when compact.

Dist.—Easily recognised by its great hardness.

Occ.—In mica-schist, gneiss, and other allied rocks; in metamorphic limestone; also in alluvial gravels. The sapphire is the beautiful blue variety, highly valued as a gem; it is sometimes of other colours, but blue is the one most prized. The impure earthy variety is known as emery, but it frequently contains magnetite in fine grains mixed with it.

Ruby. Spinel.

Isometric. Always in crystals.

Comp.—$MgAlO_4$. Magnesia 28 per cent., alumina 72 per cent.

Colour.—Red, and passes into various shades of blue, green, brown, and yellow.

Lustre.—Vitreous. *H.*=8. *G.*=3·5 to 4.

Dist.—By the forms of the crystals and by their great hardness.

Fig. 10.

Occ.—Scattered in granular limestone and in various archæan and volcanic rocks; in Burma and Ceylon they are largely mined, the bright red variety, or spinel ruby, being greatly valued as a gem. *Pleonaste*, another variety, contains iron, and is quite black.

Cryolite.

Monoclinic, but generally massive.

Comp.—$3NaF + AlF_2$. Aluminium 13 per cent., sodium 33 per cent., fluorine 54 per cent.

Colour and streak.—White.

H.=1 to 1·5. *G.*=3. Translucent.

Dist.—Fuses easily in a candle-flame; looks like ice.

Occ.—Occurs in the regions of volcanoes and geysers in sheets. It is a valuable mineral, being the almost sole source from which the metal aluminium is obtained.

Alunogen. Hydrous Aluminium Sulphate.

In white incrustations.

Comp.—Sulphur trioxide 36 per cent., alumina, 15 per cent., water 49 per cent.

H.=1·5 to 2. *G.*=1·5 to 1·8.

Dist.—It is known by its alum taste and by its yielding water in a closed tube when heated.

Occ.—In volcanic regions, and in shales in the coal measures; also in beds in the lias formation. It has been formed by the action of sulphuric acid, engendered by the decomposition of iron pyrites, upon the alumina in the rocks. A valuable mineral.

Alunite. Alum Stone.

Rhombohedral; cleavage good in one direction.

Comp.—Sulphur trioxide 38·5 per cent., alumina 37 per cent., potash 11·5 per cent., water 13 per cent.

Colour.—White or grey; sometimes red.

Lustre.—Of crystals, vitreous. Transparent to translucent.

H.=4. *G.*=2·5 to 2·75.

Dist.—Infusible, but soluble in sulphuric acid; the solution not forming a jelly.

Occ.—Found in volcanic regions. It is a valued ore, and is used in dyeing processes.

Turquoise.

Massive.

Comp.—Phosphorus pentoxide 22·5 per cent., alumina 47 per cent., water 20·5 per cent.

Colour.—Pale blue. *Lustre.*—Like sealing-wax.

H.=6. *G.*=2·75.

Dist.—Is bluer and harder than malachite: green feldspar is fusible; turquoise B. B. turns brown and colours the flame green.

Occ.—A rare and highly valued gem. It is found chiefly in Persia, and is said to be derived from an ancient trachyte (Section III., page 92). It occurs in highly disturbed vulcanic regions.

Wavellite.

Fig. 11.

Orthorhombic; in forms as in fig. 11.

An aluminous phosphate occurring in crystalline clay slate.

Various light colours. *H.*=3·75. *G.*=2·5.

MAGNESIUM.

Brucite. Magnesium Hydrate.

Rhombohedral; in hexagonal prisms and plates, and thin leaves; also fibrous.

Comp.—MgO + water. Magnesia 69 per cent., water 31 per cent.

Colour.—White, greyish or greenish.

Lustre.—Pearly. Translucent. Flexible.

H.=2·5. *G.*=2·5.

Dist.—Looks like gypsum, but is soluble in acid. B. B. infusible.

Occ.—In volcanic regions, and in serpentine and olivine rocks.

Epsomite. Epsom Salt. Magnesium Sulphate.

Orthorhombic, but crystals not so frequently found as incrustations.

Comp.—$MgSO_4$. Sulphur trioxide 32·5 per cent., magnesia 16·5 per cent., water 51 per cent.

Colour.—White. *Lustre.*—Vitreous.

Very soluble in water, with a bitter taste.

H.=1. *G.*=2·5. *Dist.*—By its solubility and taste.

Occ.—In and around mineral springs; in cavities through which mineral springs pass, and in sheets on the floors of caves.

Magnesite. Magnesium Carbonate.

Rhombohedral; also massive, tuberous, and fibrous.

Comp.—$MgCO_3$. Magnesia 47·5 per cent., carbon dioxide 52·5 per cent.

Colour.—White, or various whitish impure colours. *Opaque when massive.*

H.=4. *G.*=3.

Dist.—Can be distinguished from calcite and dolomite by adding sulphuric acid to a concentrated solution, when no calcium sulphate is precipitated.

Occ.—With olivine and serpentine rocks. A useful ore for the manufacture of Epsom salts.

CALCIUM.

Fluorite. Fluorspar. Calcium Fluoride.

Isometric; in cubes. Rarely found in state in which crystals cannot be determined. Cleavage perfect.

Comp.—CaF_2. Calcium 51 per cent., fluorine 49 per cent.

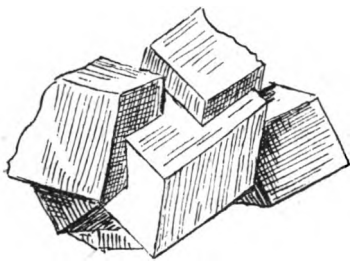

Fig. 12.

Colours.—White, blue, violet, green, pink, and many others; usually clear and bright. Transparent to translucent.

H. = 4. *G.* = 3 to 3·25. Brittle.

Dist.—Its softness, its phosphorescence when heated, and its bright colours serve to distinguish it. With sulphuric acid it will afford a gas which etches glass, but is dangerous to inhale.

Occ.—Fluorite occurs in gneiss, mica schist, and limestone. It is a common gangue for lead ores, and with copper and tin and others it frequently forms a portion of a mineral vein (see p. 146, Section IV.). In Derbyshire, England, a very compact fluorite, called Blue John by the miners, is worked into vases and ornaments.

Gypsum. Hydrous Calcium Sulphate.

Monoclinic. Crystals often twinned. Also massive and compact.

Comp.—$CaSO_4$ + water. Sulphur trioxide 46·5 per cent., lime 32·5 per cent., water 21 per cent.

Colours.—White, pinkish, brownish.

H.=2. *G.*=2·3. Transparent to translucent.

Dist.—Readily distinguished by its softness, and by its turning opaque with loss of water when heated.

Occ.—Is found in beds and sheets in permian and other *sedimentary* rocks, often associated with sodium chloride or common salt. 'Satin spar' is very fibrous, and looks like satin; 'alabaster' is compact and fine-grained; 'selenite' is

in clear plates. When burnt and crushed fine gypsum is named 'plaster of Paris.' Alabaster is useful for ornaments and statues.

Anhydrite. Calcium Sulphate.

Orthorhombric; cleaves in three directions. Also fibrous.

Comp.—As for gypsum, but without water.

Colours.—White, bluish, pinkish.

Lustre.—Pearly. Transparent to translucent.

H. = 3. *G.* = 2·96.

Dist.—By giving no water on heating in closed tube and by its crystallisation.

Occ.—With gypsum; in limestones and sandstones.

Scheelite. Calcium Tungstate.

Tetragonal. *H.* = 4·5 to 5. *G.* = 6·0.

Comp.—$CaWO_4$. *Colour.*—White, red, green, brown.

Dist.—By high specific gravity, and non-effervescence in acids.

Occ.—Rare and unimportant.

Apatite. Calcium Phosphate.

Hexagonal; usually massive and compact.

Comp.—Calcium phosphate, with calcium chloride and calcium fluoride.

Colour and streak.—Various shades of green; streak colourless.

Lustre.—Vitreous. *H.* = 5. *G.* = 3·2. Brittle.

Dist.—Infusible B. B.; soluble in acid without effervescence.

Occ.—In schistose and hornblende rocks; in granular limestone; in small crystals in most vulcanic and trap rocks. Fossil excrements, called 'coprolites,' are of this composition, and are worked for manure purposes.

Calcite Calc-spar. Calcium Carbonate.

Hexagonal, with easy cleavage. Also compact, fibrous, and in layers.

Comp.—$CaCO_3$. Carbon dioxide 44 per cent., calcium oxide 56 per cent.

Colours.—White, topaz yellow, rose red, violet when transparent; when opaque white, grey, reddish, &c.

H.=3. *G.*=2·7 when pure. Transparent to opaque.

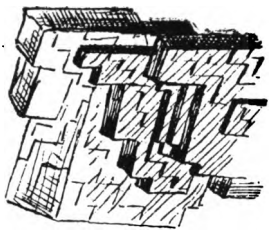

Fig 3 —Iceland Spar.

Dist.—It is distinguished by its softness, by its great effervescence in acids, and its complete infusibility.

Occ.—Forms the gangue of many mineral veins, and occurs in various impure and characteristic varieties in all the older geological systems.

The following varieties are also known :—

'Iceland spar' in clear transparent rhombohedral crystals. 'Dog-tooth spar' and 'nail-head spar' are fanciful names given to varieties of crystals of the shapes indicated by the titles.

'Limestone' is the name given to massive calcite.

'Chalk' is a white earthy variety formed of fossil marine organisms.

'Hydraulic limestone,' 'pisolite,' 'oolite,' 'calcareous tufa,' are also varieties which are described further on (see Section III., page 102).

Aragonite.

The same as calcite, but crystallises in the orthorhombic system, an instance of di-morphism (see page 29).

Dolomite. Magnesian Limestone.

Hexagonal, with perfect cleavage; but usually found massive and granular; sometimes concretionary.

Comp.—Same as for calcite ($CaCO_3$), but some of the calcium oxide replaced by magnesia.

Colours.—Usually white, yellowish, or greyish.

Lustre.—Of crystals, vitreous or pearly. Translucent.

H.=3·5 to 4. *G.*=2·85. Brittle.

Dist.—Harder than calcite, which it looks like, but does not effervesce nearly so freely in acids.

Occ.—It occurs, well developed, in permian and triassic strata, and forms, when compact, a very valuable and durable building-stone.

BARIUM.

Barytes. Heavy Spar.

Orthorhombic, with cleavage perfect; also massive, columnar, fibrous, and granular.

Comp.—$BaSO_4$. Sulphur trioxide 34 per cent., baryta 66 per cent.

Colours.—White and various impure tints to brown; streak whitish.

Lustre.—Vitreous. Transparent to translucent.

H.=2·5 to 3·5. *G.*=4·5.

Dist.—Easily distinguished by its great specific gravity, and by its infusibility B. B.

Occ.—Is a common gangue in mineral veins (see Section IV., page 146), and occurs in fissures in disturbed districts.

Witherite. Barium Carbonate.

Orthorhombic; also globular, and sometimes massive.

Comp.—$BaCO_3$. Carbon dioxide 23 per cent., baryta 77 per cent.

Colours.—Yellowish, greyish to white when crystallized.

H.=3 to 4. G.=4·3. Translucent to transparent.

Dist.—B. B. splutters and fuses, tingeing the flame green.

Occ.—Rare. Is used in the manufacture of beet-sugar; and also for plate-glass.

STRONTIUM.

Celestine. Strontium Sulphate.

Orthorhombic.

Comp.—$SrSO_4$. Sulphur trioxide 44 per cent., strontia 56 per cent.

Colours.—White, green, blue. Transparent.

H.=3·5. *G.*=4. Brittle.

Dist.—Distinguished by the bright red colour it imparts to the blowpipe flame.

Occ.—In permian marls and sandstones, accompanying gypsum and rock salt; often in hollow $CaCO_3$ nodules.

Strontianite. Strontium Carbonate.

Orthorhombic.

Comp.—$SrCO_3$. Carbon dioxide 30 per cent, strontia 70 per cent.

Colours.—Pale greenish, bluish white. Transparent.

H.=3·5 to 4. *G.*=3·7.

Dist.—Its effervescence with acids and bright red colour imparted to blowpipe flame are distinguishing features. Calcium flame more yellow and less brilliant.

Occ.—In permian strata, in limestones, and sometimes associated with galena.

POTASSIUM.

Sylvanite. Potassium Chloride.

Isometric.

Comp.—KCl. Chlorine 47·5 per cent., potassium 52·5 per cent.

Taste.—Nearly like common salt, from which it is distinguished by giving a violet colour to the blowpipe flame.

Occ.—In association with rock-salt in beds and sheets. A constant ingredient of sea-water.

Nitre. Potassium Nitrate.

Orthorhombic, usually in needle-shaped crystals and in incrustations.

Comp.—KNO_3 (or $K_2O+N_2O_5$). Nitrogen pentoxide 53 per cent., potash 47 per cent.

Taste.—Saline and cooling.

Colours.—Clear, transparent, reddish tint.

H.=2. G.=1·97. Brittle.

Dist.—Burns on a red-hot coal. It resembles sodium nitrate, but does not liquefy on exposure to moist air.

Occ.—In incrustations in dry countries in caves, and on the surface of the ground. Valuable for the manufacture of gunpowder.

SODIUM.

Halite. Sodium Chloride. Common Salt.

Isometric; also massive and stratified.

Comp.—NaCl. Chlorine 61 per cent., sodium 39 per cent.

Colour.—White, greyish, or reddish.

Taste.—Saline. Transparent to translucent.

H.=2. *G.*=2·25.

Dist.—By its solubility and taste.

Occ.—In extensive beds, some over 1,000 feet thick. Occurs in vast masses in jurassic rocks, and in others of all geological periods. Is forming at the present day wherever saline waters evaporate. Usually associated with gypsum. Constitutes 80 per cent. of the solid matter in solution in sea-water. Valuable; necessary for human life.

Borax. Tinkel. Hydrous Sodium Borate.

Monoclinic.

Comp.—A compound of sodium with boracic acid and water.

Colour.—White to colourless. Transparent.

Taste.—Sweetish, alkaline.

H.=2 to 2·5. *G.*=1·72.

Dist.—B. B. swells up and froths to many times its size, finally sinking to a glassy globule.

Occ.—Found incrusting the shores of certain alkaline waters.

Nitrates. Sodium Nitrate.

Hexagonal; also found in crusts.

Comp.—$NaNO_3$. Nitrogen pentoxide 63·5 per cent., sodium 36·5 per cent.

Colour.—White, greyish. Transparent.

H.=2. *G.*=1·8.

Taste.—Cooling.

Dist.—Solubility, and liquefies on exposure to moist air.

Occ.—In thick crusts and sheets on the surface of the earth; associated with gypsum and common salt. Largely mined in Chili and used for fertilising soil, and in the manufacture of nitric acid.

AMMONIUM.

SALMIAK. SAL AMMONIAC. AMMONIUM CHLORIDE.

In white crusts.

Comp.—NH_4Cl. A compound of ammonia and hydrochloric acid.

Colour.—White, yellowish, grey, &c.

Taste.—Pungently saline, by which it can always be distinguished.

Occ.—In many volcanic regions, but is now chiefly obtained, for commerce, from the ammonia liquors of gasworks.

In addition to the above-described minerals there are included in the Basic Group the following metals with their ores, but of them it is not necessary to speak further:

Beryllium, cadmium, cæsium, cerium, chromium, didymium, erbium, gallium, indium, lanthanum, lithium, niobium, rubidium, ruthenium, scandium, selenium, tantalum, thallium, terbium, thorium, vanadium, ytterbium, yttrium, zirconium.

They are all more or less rare and unimportant.

CHAPTER III

Description of Minerals [Silica and Silicates, Hydrocarbons]

3. SILICA GROUP.

E. SILICA SUBDIVISION.

QUARTZ.

Rhombohedral, generally in six-sided prisms with six-sided pyramids as in fig. 14. Also massive, flint-like, and compact.

Comp.—SiO_2. Oxygen 53·3 per cent., silicon 46·7 per cent.

Colours.—White and various shades of grey, yellow, blue, green, brown, and black. Transparent (when pure) to opaque.

H.=7. *G.*=2·75.

Lustre.—Of crystals, adamantine; of compact varieties, vitreous.

Dist.—By its hardness, by the absence of cleavage in the crystals, by its infusibility B. B., and by its insolubility in acids, quartz may easily be recognised.

Occ.—Quartz rarely occurs pure. It contains, among other impurities, hornblende, rutile, tourmaline, hematite, pyrite and limonite. Massive, in veins and sheets. Quartz is a common rock, and occurs, traversing the fissures, in rocks of all ages. It forms the gangue of many mineral veins, and gold is frequently associated with it. Crystals of quartz frequently occur in cavities in rocks, and the crystals often contain liquid-filled cavities in themselves.

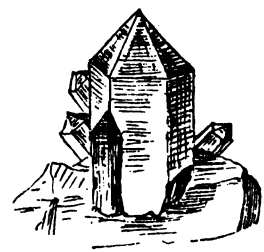

Fig. 14.

The following varieties of quartz are common:—

Rock crystal.—Pure transparent silica, sometimes of great beauty.

Amethyst.—Transparent amethyst-coloured; valuable as a gem.

Aventurine.—Reddish or brownish with yellow-coloured mica spangles.

Rose quartz, smoky quartz, and *milky quartz* are varieties of the nature indicated by their names.

Ferruginous quartz.—The so-called '*burnt quartz*' of the miner; it is brownish, reddish, or yellowish, according to the stage of decomposition of the pyrites it contains.

Chalcedony.—Massive and translucent, with a waxy lustre; frequently contains fluid (sometimes as much as a quarter of a pint); chalcedony is often found as stalactites having been precipitated from siliceous waters passing through cavernous rocks.

Cornelian.—Bright Indian red chalcedony; used as a gem.

Agate.—Chalcedony with the colours arranged in bands or spots; moss agates have iron impurities in moss-like masses in the body of the rock; somewhat valuable.

Onyx.—An agate with more or less parallel lines of black and white, or red and white. Valuable for seals and ornaments.

Catseye.—A greenish chalcedony, nearly transparent, with an internal fibrous structure, giving the appearance indicated by the name.

Flint, hornstone, and *chert* are impure dark-coloured varieties, occurring in nodules and beds.

Jasper.—A dull red opaque variety; polishes beautifully.

Bloodstone.—A dark green variety with blood-red spots coloured by iron oxide. Valued for rings and seals in jewellery.

Touchstone.—A deep velvet black; used for testing the quality of precious metals.

OPAL.

Compact; breaks with a fracture like thick bottle-glass.

Comp.—SiO_2 with water.

Colours.—White, and all varieties but black.

Lustre.—Waxy or subvitreous, like porcelain.

H.=6. *G.*=2·1.

Dist.—Differs from quartz in its lustre and in having no sign of crystallisation.

Occ.—Opal occurs in veins and strings in old and highly altered rocks. Also near geysers and in volcanic regions.

Precious opal.—Has a milk-white colour, but when turned in different lights exhibits a play of exquisitely delicate tints of various shades of colour, blue, fire-red, green, and brown, &c. It is a gem of great beauty and some considerable value.

Wood opal.—Is wood silicified, and contains traces of the original wood structure; generally brown or yellowish.

TRIDYMITE.

Is pure silica with the hardness and specific gravity of opal. It occurs in ancient imperfectly crystallised granyte rocks. Its perfect form is shown in fig. 15.

FIG. 15.

F. ANHYDROUS[1] *SILICATE SUBDIVISION.*

(*a*) *Bisilicates.*

In this subdivision the *bisilicates* contain one molecule of silicon with one molecule of an element in the protoxide state, or $\frac{1}{3}$ of a molecule in the sesquioxide state; the *unisilicates* contain one molecule of silicon with two molecules of an element in the protoxide state, or with $\frac{2}{3}$ of a molecule in the sesquioxide state; and the *subsilicates* contain a less proportion still. A knowledge of most of these silicates is desirable, inasmuch as they are the chief substances which form rocks.

EUSTATITE. BRONZITE.

Orthorhombic. *H.*=5·5. *G.*=3·2.

Comp.—A silicate of magnesia.

[1] *Anhydrous*, i.e. without water.

Colours.—Greyish, yellowish, greenish, bronze, sometimes metallic.

Dist.—Looks like amphibole, but is orthorhombic and infusible B. B.

Occ.—Found in basic rocks, as the result of alteration of other minerals.

Wollastonite. Tabular Spar.

Monoclinic; often in flat table-like crystals.

Comp.—A silicate of lime. *H.*=4·75. *G.*=2·87.

Colour.—White. *Lustre.*—Vitreous to pearly. Translucent. Brittle.

Dist.—Distinguished from asbestos by turning into jelly in acids; from zeolites by absence of water; from feldspar in the fibrous appearance of a cleaved surface.

Occ.—In garnet-rock, in granyte, granular limestone, and basalt.

Pyroxene. Augite.

Monoclinic, with good cleavage in two directions.

Comp.—Generally a lime-magnesia silicate, but also containing iron, manganese, zinc, potash, and soda.

Colours.—Various shades of green, brown, and reddish.

H.=5 to 6. *G.*=3·3.

Has many varieties, of which the following are the chief and most easily recognised:—

Diopside.—In clear, light, olive-green crystals.

Coccolite.—In granular olive-green masses.

Augite proper.—In black and dark green or brown crystals, rather dull, and of the form shown in fig. 16.

Fig. 16.

Diallage.—In their leaves, reddish brown or brown in colour.

Occ.—Pyroxene is a common rock-forming mineral, occurring in nearly all the igneous and vulcanic rocks; the crystals are for the most part small, but occasionally are found a foot in length.

Rhodonite. Manganese Spar.

Triclinic; also massive.

Comp.—A silicate of manganese.

Lustre.—Vitreous. Transparent to opaque.

Colour and streak.—Deep flesh-red, but often of various other dark shades; turns black on exposure.

H.=6. *G.*=3·4 to 3·7.

Dist.—Might be mistaken for flesh-coloured feldspar, but has a higher specific gravity, and in borax B. B. forms a violet bead which turns brown red when cold.

Occ.—In vulcanic rocks and granular limestone. It is sometimes employed as a gem.

Amphibole. Hornblende.

Monoclinic; often in columnar forms, fibrous and silky.

Comp.—A silicate of iron, manganese, and lime, but often contains soda and potash. Occasionally contains aluminium.

Colours.—Various shades of light and dark green to black.

H.=5 to 6. *G.*=3·1 to 3·4.

Dist.—Easily known by the cleavage of the crystals and by the columnar structure, which is most general.

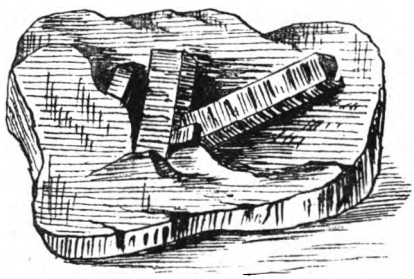

Fig. 17.

There are many varieties, of which the following are the more general:—

Tremolite.—A white, light green, or greyish variety.

Actinolite.—A light-green fibrous variety, occurring in needle-like aggregates.

Asbestos.—A light-green fibrous variety with very fine silky fibres like flax.

Mountain leather.—The same, but in tough greasy sheets.

Nephrite.—A light-green variety, compact, and easily cut with a knife. It is used for ornaments and images in China.

Hornblende.—A dark green or greenish black variety, occurring in crystals and in masses as rock.

Occ.—Amphibole in its several forms is a widely distributed rock; it occurs in many eruptive rocks as isolated crystals and as thick masses. It is closely related to pyroxene. Asbestos is an unconsumable variety, and is employed in the arts for manufacturing fire-proof articles, for steam packing and for paints; when of long and fine fibre, asbestos is worth about 20*l.* per ton.

BERYL. EMERALD.

Hexagonal.

Comp.—A silicate of alumina and beryllium.

Colours.—Clear emerald green and various clear greenish and bluish green tints. Transparent or vitreous.

H.=8. *G.*=2·6 to 2·7.

Dist.—It is harder than apatite, and the crystals are lighter than, and of a different form to, tourmaline.

Occ.—In granyte, gneiss, and mica-schist. Aquamarine is of a vitreous sea-green colour. Emeralds are of great value, and are highly prized as gems.

(*b*) *Unisilicates.*

OLIVINE. CHRYSOLITE.

Orthorhombic; usually in imbedded grains, very small.

Comp.—A magnesian-iron-silicate.

Lustre.—Distinctly vitreous. Transparent to translucent.

Colours.—Oil green or yellow green.

H.=6 to 7. *G.*=3·5 to 3·7.

Dist.—Like green quartz, but occurs in different-shaped crystals, and obsidian, which is somewhat like; is fusible.

Occ.—Olivine occurs in volcanic rocks, basalt, and lava, in gabbro, and in small grains in several other related species. Much serpentine is, probably, altered olivine.

GARNET.

Isometric.

Comp.—Either a silicate of iron and alumina (alumina garnet), or a silicate of lime and iron (iron garnet).

Colours.—Red and brown of various deep shades; a rare mineral (chrome garnet) has a green colour.

H.=6 to 7. *G.*=3 to 4·3. *Lustre.*—Adamantine to vitreous.

Dist.—Garnets are distinguished from rubies by their deeper colour and by their inferior hardness.

Occ.—Garnets occur in granyte, gneiss, mica schist, granular limestone and other metamorphic rocks; also in alluvial sands and gravels. They are used for jewels, but are not greatly valued, unless very fine, on account of their dark colour.

ZIRCON.

Tetragonal.

Comp.—A silicate of zirconium.

Colours.—Dark brown, reddish, and red; also white yellow, greyish white when not clear.

Lustre.—Nearly adamantine.

H.=7·5. *G.*=from 4 to 5.

Dist.—It is known best by its lustre and the form of crystallisation, rare among silicates.

Occ.—In granyte, gneiss, granular limestone, and some igneous rocks. Inferior diamonds, sold by the Arab traders in Ceylon, are not infrequently clear yellow-coloured zircons. The jacinth of Scripture was a purple or red zircon.

EPIDOTE.

Monoclinic; also forming rock masses.

Comp.—A lime-iron-aluminium silicate.

Colours.—Yellow-green, grey, or brown. Translucent to opaque.

Lustre.—Vitreous. *H.*=6 to 7. *G.*=3·25 to 3·5.

Dist.—Epidote is easily told by its peculiar green colour.

Occ.—It is often associated with hornblende, and occurs in many crystalline rocks; occurs in the cavities of amygdaloidal rocks.

Muscovite, White Mica.

Monoclinic; in plates and scales.

Comp.—A silicate of alumina with iron and potash; often contains water, fluorine, and bromine.

Lustre.—Pearly. Transparent. Elastic.

H.=2. *G.*=2·7 to 3.

Colours.—White or yellowish and brownish.

Dist.—Mica, of all kinds, is readily distinguished by its characteristic spangled appearance and by its elasticity.

Occ.—Muscovite-mica is a common constituent of many rocks, such as granyte, gneiss, mica-schist slates, and sandstones. The more watery species have a greasy feel, and are often mistaken for talc, but the latter is inelastic.

Pholgopite. Golden Mica.

Like the preceding, but contains more fluorine. Is occasionally taken for gold, but is easily distinguished by being split off in flakes.

Biotite. Black Mica

Monoclinic; usually in plates and scales.

Comp.—An aluminous-magnesian-iron silicate, with potash, soda, fluorine, and water.

Colours.—Dark brown, green, or black. Translucent.

Lustre.—Pearly. Elastic, but less so than muscovite.

H.=2·5 to 3. *G.*=2·7 to 3·1.

Dist.—Unmistakable for any other mineral.

Occ.—Is a more common constituent of granyte than muscovite; occurs in many metamorphic rocks; *not* so common as muscovite in slates and sandstones.

NEPHELINE.

Hexagonal; sometimes massive.

Comp.—An alumina silicate, with soda, lime, potash, and iron.

Colours.—White or grey. Transparent to opaque.

Lustre.—Vitreous. *H.*=6. *G.*=2·5 to 2·6.

Dist.—It gelatinises in acids and B. B. fuses to a colourless glass.

Occ.—A constituent of clink-stone or phonolyte, of some metamorphic rocks, and occasionally of doleryte.

SODALITE.

Isometric.

Comp.—An aluminous-soda silicate, with chlorine and sodium.

Colours.—Brown, blue, grey. *Lustre.*—Vitreous.

H.=6. *G.*=2·25 to 2·4.

Dist.—B. B. fuses and froths up, sinking to a colourless glass.

Occ.—Sodalite is a constituent of many vulcanic rocks in small isolated crystals.

Lapis Lazuli. Ultramarine.

Isometric, but generally incrusting.

Comp.—An aluminous silicate with sulphuric acid, iron, soda, lime, and sulphur; sometimes water.

Colour.—A beautiful rich blue.

H.=5·5. *G.*=2·3 to 2·5.

Dist.—It is easily recognised by its colour.

Occ.—Occurs in Persia and China in syenyte and granular limestone. Lapis lazuli is greatly prized on account of its beautiful colour, for inlaid mosaic work and for various ornaments. It is the real source of the unadulterated paint ultramarine.

LEUCITE.

Isometric; generally in white crystals. Often twins.

Comp.—A silicate of alumina and potash.

Colour.—White greyish. Translucent.

Lustre.—Very glassy. *H.*=5·5. *G.*=2·5. Brittle.

Dist.—Looks like analcite but harder; and infusible.

Occ.—In lavas.

Anorthite. Lime Feldspar.

Triclinic; also massive and lamellar.

Comp.—A silicate of alumina and lime.

Colours.—White, greyish, pinkish. *H.*=5·5. *G.*=2·7.

Occ.—Anorthite occurs in eruptive crystalline rocks; in gabbro and dolerytes.

Labradorite. Lime-Soda Feldspar.

Triclinic; also massive.

Comp.—A silicate of alumina and lime, with 4·5 per cent. of soda.

Colours.—Dark grey or brown; white and colourless.

H.=6. *G.*=2·7.

Occ.—Labradorite is the chief constituent of a section of quartzless-plagioclase rocks (see Section III., page 94).

Oligoclase. Soda-Lime Feldspar.

Triclinic; cleavage good; massive.

Comp.—A silicate of alumina with soda and 5 per cent. of lime.

Colours.—Usually white; also pinkish, greyish, and greenish.

H.=6 to 7. *G.*=2·5 to 2·7.

Occ.—One of the feldspars included under the name *Plagioclase*; it is a constituent of syenyte, porphyryte, trachyte; but more generally of dioryte, andersyte, tonalyte, and propylyte.

Albite. Soda Feldspar.

Triclinic; tabular and massive.

Comp.—A silicate of alumina with soda.

Colour.—White. Transparent to sub-translucent.

Occ.—The chief occurrence of albite is in granyte veins; sparingly in gneiss.

Orthoclase. Potash Feldspar.

Monoclinic. Usually found in thick crystals; also massive.

Comp.—A silicate of alumina with potash.

Colours.—White, grey, and flesh red. A green variety is called '*amazon-stone*,' and an *opalescent* variety is termed '*moonstone*.' '*Sanidine*' is a clear glassy variety occurring in many syenitic rocks.

H.=6. *G.*=2·55.

Occ.—Orthoclase, or common feldspar, is a constituent of granyte, granityte, granulyte, felsyte, rhyolyte, and many other eruptive rocks. It occurs in crystals of great size in

some granytes. Felsyte is nearly an imperfectly crystallised orthoclase.

All the feldspars can be readily recognised by the form of their crystals, and by their not gelatinising with acids (except anorthite). A minute parallel lining or striation will always distinguish oligoclase from orthoclase, and labradorite is easily known by its iridescent (or rainbow-like) sheen in different lights. No feldspars are fibrous.

(c) *Subsilicates.*

TOURMALINE.

Rhombohedral; usually in long prisms of from 6 to 12 sides.

Comp.—A silicate of alumina with *boron*, magnesia, iron, lime, soda, and potash.

Colours.—Black, brown, green; colourless and grey rare.

Lustre.—Vitreous. Transparent to translucent.

H.=7. *G.*=2·89 to 3·3.

Dist.—Easily known by the test for boron (see Section V., page 223).

Occ.—Tourmaline (schorl) is a common constituent of granyte, gneiss, schists, quartzyte, and other eruptive and crystalline rocks. In granyte it appears to be associated with cassiterite. Clear crystals of red and green are valued as second-rate gems, and some of the clear varieties are used for polariscope purposes.

ANDALUSITE.

Orthorhombic; often in square prisms, as per fig. 18, taken from Dana's 'Manual of Mineralogy.'

Fig. 18.

Comp.—Silica 37 per cent., alumina 63 per cent.

Colours.—Grey and pink. Translucent to opaque. Brittle.

H.=7·5. *G.*=3·2. Tough.

Dist.—Generally known by the forms of its crystals.

Occ.—*Chiastolite*, a variety, occurs in slates; andalusite is not very common, but occurs in fine grains in metamorphic rocks.

TOPAZ.

Orthorhombic; good cleavage parallel to base.

Comp.—Silica 16 per cent., silicon fluoride 28 per cent., alumina 56 per cent.

Colours.—Pale sherry-yellow; also white, greenish, bluish, &c. *Streak.*—White. *Lustre.*—Vitreous. Transparent to translucent.

H.=8. *G.*=3·5.

Dist.—Easily known by its hardness and cleavage.

Occ.—Topaz, which is valued as a gem, is found in metamorphic rocks, and is frequently associated with tourmaline and tin; in rhyolyte, and also in alluvial sands and gravels.

Yellow quartz, cairngorms &c. are frequently called topaz, and are sold as such although greatly inferior in lustre and somewhat in hardness.

SPHENE.

Monoclinic. Usually occurs in flat nail-head-like crystals, clustered together; also wedge-shaped.

Comp.—A silicate of lime and titanium.

Colours.—Brown, black, grey-brown, and soft velvety dark green.

Lustre.—Resinous. Transparent to opaque commonly.

H.=5. *G.*=3·5.

Dist.—Sphene is known by its characteristic form of crystallisation, and by its fusing B. B. with considerable frothing.

Occ.—It is not an important rock-forming mineral. It occurs in granyte, syenyte, and granular limestone; often associated with graphite in gneiss.

G. HYDROUS[1] SILICATES.

(d) *General Section.*

In this section the minerals are merely bisilicates, unisilicates, and subsilicates *with* water.

APOPHYLLITE.

Tetragonal; with good base cleavage.

Comp.—A hydrous silicate of lime with potash and soda, the water being about 16 per cent.

H.=4·5. *G.*—2·3 to 2·4. Transparent to opaque.

Occ.—Found in the cavities in doleryte and basalt.

PREHNITE.

Orthorhombic, but usually incrusting and botryoidal.

Comp.—A silicate of alumina and lime; water 4·5 per cent.

Colour.—A clear light green, rather like aquamarine.

Lustre.—Vitreous. Transparent to translucent.

H.=6. *G.*=2·8 to 2·96.

Dist.—It is distinguished from aquamarine and green chalcedony (chrysoprase) by giving off water in a tube when heated, and by fusing B. B.

Occ.—Occurs in the cavities of orthoclase and oligoclase rocks; common in doleryte.

(e) *Zeolite Section.*

The minerals in this section are like feldspar in composition, but are found in cavities in trap rocks, and contain water combined with their elements.

All these minerals fuse easily B. B., frothing up with great vigour; they all yield water when heated in a closed tube, and gelatinise, after decomposition, in hydrochloric acid.

[1] *Hydrous*, i.e. with water.

THOMSONITE.

Orthorhombic; often fibrous and acicular.

Comp.—A hydrous silicate of alumina with lime and soda, the water averaging 13·5 per cent.

Colour.—White. *Lustre.*—Vitreous or pearly.

H.=5·5. *G.*=2·3. Transparent to translucent.

Occ.—In doleryte, clinkstone, and in lavas.

NATROLITE.

Orthorhombic; often in very fine needles.

Comp.—A hydrous silicate of alumina with soda, the water averaging 10 per cent.

Colours.—White, greyish, and yellow.

H.=5. *G.*=2·25. *Lustre.*—Vitreous. Brittle.

Occ.—Found in cavities in doleryte and lavas.

ANALCITE.

Isometric.

Comp.—A silicate of alumina and soda, with 8·17 per cent. of water.

Colours.—Transparent, opaque, milky-white, and greyish.

Lustre.—Vitreous. *H.*=5. *G.*=2·25.

Occ.—In cavities in doleryte, diabase, and lavas; sometimes in granyte and syenyte.

STILBITE.

Monoclinic; usually in spear-like crystals.

Comp.—A silicate of alumina with lime and 17 per cent. of water.

Colour.—Generally white. Translucent.

Lustre.—Pearly. *H.*=3·5. *G.*=2·1.

Occ.—As for the other zeolites.

(*f*) *Talc Section.*

This section embraces the thin foliated varieties of silicates, with a greasy touch. Chlorite is derived from the decomposition of many silicates singly and together.

TALC.

Orthorhombic; but generally in thin foliated leaves.

Comp.—Silica 63 per cent., magnesia 33 per cent., water 4 per cent.

Colour.—Light green or whitish green. Flexible.

H.=1. *G.*=2·5 to 2·8. *Lustre.*—Pearly and feels greasy.

Dist.—Its foliated structure and inelasticity should distinguish it from hydromica.

Occ.—It occurs in masses as *soapstone*, which is an impure many-coloured talc rock; as *indurated talc*, which is slaty; and in fine granular masses of a white colour called *French chalk*. In thin crystals it is a common constituent of some slates, and is often associated with gold. It is used for adulterating soaps, for lubricating purposes, and for stone polishing. Soapstone, which is easily cut, is largely used in China for carving images and ornaments.

SEPIOLITE. MEERSCHAUM.

Compact and earthy.

Comp.—Silica 61 per cent., magnesia 27 per cent., water 12 per cent.

Colour.—White. Opaque.

H.=2 to 2·5. *G.*=2·6.

Dist.—Is nearly infusible, and gives off much water in a closed tube.

Occ.—It occurs in stratified masses, and in earthy deposits (which float on water). It is employed for making pipes, and takes a most beautiful polish.

SERPENTINE.

See Section III., page 93.

CHLORITE.

Chlorite is a dark green silicate of magnesia, with (generally) some iron, alumina, and manganese.

It contains from 10 per cent. to 15 per cent. of water.

H.=1 to 1·5. *G.*=from 2·5 to 3.

Chlorite is the result of the alteration of some anhydrous magnesian and aluminous silicate or silicates. It commonly occurs in slates and schists, and can be frequently seen by the green stain it leaves, around the edges of altering crystals in many crystalline rocks. It occurs in vein quartz, and is a not infrequent associate of rich gold shoots in such.

4. HYDROCARBON GROUP.

H. OILS, RESIN, WAX.

PETROLEUM.

Petroleum is a mineral oil with a density of 0·75. It is soluble in benzine. It is readily recognised by its density, its odour, and by its power of ignition.

It has been formed by the decomposition of animal and vegetable substances, which once lived and flourished upon the mud which is now consolidated into the shales in which it is found.

Petroleum exists in rocks of all ages.

Carboniferous shales yield it in abundance, and even some sandstones give good returns, although in the latter case it is probable that the petroleum exists in cavities within the earth's crust beneath the sandstones.

Petroleum is largely used for lighting purposes, for fuel, and for different medical compounds.

AMBER.

Amber occurs in irregular fragments.

Colour.—Yellow or brownish.

H.=2·5. *G.*=1·18. *Lustre.*—Resinous.

It becomes electric, and will attract light bodies when rubbed.

Occ.—In tertiary strata in loose crumbling deposits.

Amber is a mineralised vegetable resin or gum. It frequently contains embedded insects in a perfect state of preservation. When clear or well marked with a milky stain, it is highly prized as an ornament of jewellery.

Mountain Tallow. Ozokerite.

A hydrocarbonous compound of a soft nature; easily scratched with the thumb-nail, and having an odour of paraffine. It appears like a wax, and is of various shades of brown. It is used for the manufacture of candles.

BITUMEN.

A soft, elastic, black hydrocarbon, with a feel like that of soft india-rubber.

Comp.—Carbon 85·5 per cent. Hydrogen 13·5 per cent.

Burns readily with a smoky yellow flame.

G.=0·9 to 1·25.

J. ASPHALTUM. COALS.

ASPHALTUM.

Asphaltum occurs in masses near the Caspian and Dead Seas. In Trinidad there is a lake of it, the centre of which is boiling, while the shores are covered with the cooling and cooled hardened pitch. It occurs in a similar manner in Peru.

Burns with a bright flame. Is soluble in camphene.

Asphaltum is mined in some parts of the world, and is used, when mixed with gravel and other substances, for the paving of houses, halls, garden-walks, and in London and Paris largely for streets.

MINERAL COAL.

Massive, quite uncrystalline.

Colour.—Black or brown. Brittle.—Sectile.

H.=from 1 to 3. *G.*=1·2 to 1·8.

Comp.—Carbon with some oxygen and hydrogen in varying quantities.

Coal is merely mineralised vegetation (see Section IV., page 167); to some extent it has been altered by chemical action also.

The following are the chief varieties :—

Anthracite.—A good hard compact coal, containing 77 to 78 per cent. of carbon, with a trace of sulphur. It burns with a feeble blue flame.

Volatile Ingredients	3 to 10 per cent.	

Bituminous coal.—Contains up to 80 per cent. of carbon. Burns with a bright yellow flame, and yields 5 per cent. of ash and 2 per cent. of sulphur.

Volatile Ingredients	20 to 60 per cent.	

Cannel coal.—A coal much valued for fuel and for the manufacture of gas. Burns readily with a yellow flame. It is very compact, and is sometimes used for ornaments.

Volatile Ingredients	40 to 60 per cent.	

Jet.—Very like cannel coal but harder. It is much used for ornaments and mourning jewellery, and takes a very fine polish.

Coal occurs in sheets and beds in many countries and in many of the middle geological periods. The great coal-beds, or 'measures,' as they are termed, are in the Carboniferous strata, but coals of Permian, Triassic, Jurassic, and even Cretaceous ages are now known to exist (see Section IV., on Geology).

Coal is of the highest value to man, for without it we know of no fuel which could drive the countless machines engaged in our manufactures. Coal is the great civiliser of mankind in fact, for where it is wanting in the majority of cases, man cannot obtain those necessities and luxuries which have become a part of his civilisation. The coal-beds of England are computed to be able to last, at the present rate of output, over 1,000 years longer, calculated to a depth of 4,000 feet below the surface.

Lignite (brown coal).—An imperfectly mineralised young coal containing 50 per cent. to 60 per cent. of carbon. The vegetable structure is often to be still distinguished, and sulphur and pyrites (marcasite) are often present. It occurs only in the younger geological systems.

In this section we have endeavoured to describe in concise and simple language the physical structures of minerals and

their chemical compositions; mention has been made of most of the important minerals, and in the majority of cases their place among the rocks of the earth has been given.

It will be now necessary to consider the various rocks that are formed out of these minerals, their occurrences and composition, and afterwards in what manner they are instrumental in building up and altering the outer crust of the globe.

SECTION III

PETROLOGY

PETROLOGY, or, as it is sometimes called, *lithology*, is the science which investigates and treats of the origin, composition, and occurrence of the rocks forming the earth's crust.

Rocks are mineral aggregates; in other words, they are inorganic bodies formed by the chemical or mechanical union of two or more minerals. They have not, like minerals, a definite crystallisation and a definite chemical composition, but are subject to various changes which have been brought about by the conditions of their origin, or by varying circumstances which have affected them during or after their consolidation. Thus a granyte[1] may be composed of quartz, feldspar, and biotite-mica, or of quartz, feldspar, and muscovite-mica, according to the conditions under which it is crystallised out of a mineral paste; and the same granyte may pass into a gneiss, not differing at all in chemical composition but being totally different in appearance, a result due to subsequent pressure and heat.

Broadly speaking, rocks may be divided into two great classes—(A) *unstratified* (*basic, igneous*) *rocks*, which owe their origin to volcanic or vulcanic internal agency, and (B) *stratified rocks* (*sedimentary, aqueous*), which owe their origin to the influence of the various external modifying causes which have been and are at work upon the earth. There is an intermediate class—*metamorphic*—but it is merely an altered condition of rock already in existence. It should also be remembered that in this division we have included under the

[1] The 'y' is adopted in place of the 'i' in rocks, in order that there shall be no confusion between them and minerals.

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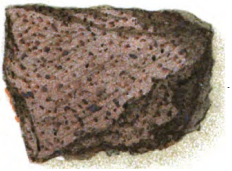

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5

C Wilson-Moore, del.

1. GRANITE. PETERHEAD.
2. LUXULIANYTE. CORNWALL.
3. PORPHYRITIC PROTOGINE. CORNWALL.
4. FELSYTE. LEICESTER.
5. RHYOLYTE. AUSTRIA.

stratified rocks those which have been built up through the agency of plant and animal life in air and sea and on land.

Petrology is a vast study, requiring a good knowledge of chemistry and mineralogy, an intimate knowledge of electricity, constant observation in the field, and elaborate and frequent study by means of the micro- or polari-scope in the laboratory.

The student must understand that the information which will be given here on this subject is only given as a guide to actual study by observation in the field, and that it is as impossible for him to learn the nature and occurrence of rocks without handling them as it is for us to describe even a tithe of those known to man. A knowledge of the origin, composition, and occurrence of rocks is, however slight, of decided advantage to those prospecting for or developing mineral veins and deposits, and with this view the following concise outlines of this study have been included in this work.

Rocks, like minerals, exhibit different forms and various physical and chemical characteristics. Certain terms are applied to rocks in accordance with these features, by which their appearance and structure are broadly expressed. For example:

A rock, when sandy, is said to be *arenaceous* (*arena*, sand); or when it is clayey it is called *argillaceous* (*argil*, clay); when it contains much lime it is called *calcareous* (*calcium*, lime); or much silica results in the term *siliceous* being applied.

A *sedimentary* rock is one which has resulted from the chemical or mechanical precipitation of sediment.

An *aqueous* rock has been formed by the action of water (*aqua*, water).

An *igneous* rock is one which has its origin in fire, either directly or indirectly (*ignis*, fire).

A *stratified* rock is one in which the lines of deposit are clearly marked in layers (*stratum*, a layer), and such layers point to an aqueous origin.

An *unstratified* rock, on the contrary, has no such lines, and with one or two exceptions such rocks are of igneous origin.

Metamorphic rocks are those in which some change has been induced after deposit (see page 157, Section IV.).

Crystalline is the term employed to express the structure of a rock which is wholly or in part formed of perfect or imperfect crystals. Many rocks which appear to the unaided eye to be compact or massive and uncrystalline exhibit complete crystalline structure when a section of the rock is examined under the microscope.

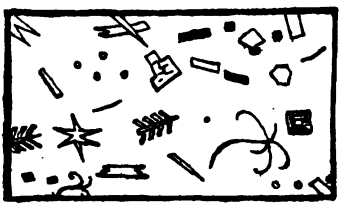


Fig. 19.

Glassy, vitreous. — Some rocks, such as obsidian and sanidin feldspar, look like pieces of glass. Nearly all igneous rocks have consolidated out of glassy masses. Most glassy rocks, however, contain minute crystals called 'microlites' (see fig. 19).

Porphyritic is the term employed to denote a structure in which a few crystals have separated themselves out and crystallised apart from the ground mass of the rock. It is a common structure in igneous rocks.

Vesicular.—Rocks are said to be vesicular when they contain spherical cavities. Pumice is a vesicular rock (see page 91).

Amygdaloidal rocks are those in which the almond-shaped (*amygdalon*, an almond) vesicles have been filled up by other minerals, brought in, probably, by percolating water. Such minerals are termed 'zeolites' (see page 77).

Spherulitic structure is best understood from an examination of fig. 21. The small circular bodies are termed 'spherulites.' It is a common structure in glassy rocks.

Fluxion (*fluo*, I flow) *structure* is the name given to a wavy, streaky appearance in rocks. It is common in rhyolyte, and marks the movement of the particles in a once molten rock.

Schistose (*schisma*, a splitting) is the name given to a structure which has been induced in rocks by metamorphism (see page 136, Section IV.). The structure consists in the arrangement in wavy irregular lines and layers of the different minerals. Mr. Darwin named the structure *foliation* (*folium*, a leaf), by which term it is also known.

Some rocks and minerals assume what is called a *concretionary* form (see page 175, Section IV.). Pyrites, siderite,

and very often dolomyte are commonly found in this way. In many cases, such as siderite and flint nodules, it would appear that the mineral has gathered around some organic nucleus (see page 188, Section IV.).

Oolitic, pisolitic.—*Oolitic* is the term used to explain the structure of a rock which is like the compact roe of a fish (*oon*, an egg; *lithos*, a stone). When the grains are larger the rock is called *pisolitic* (*pisum*, a pea). This structure is brought about by the precipitation under water of lime carbonate or other mineral salts round grains which are kept in motion by the currents (see page 181, Section IV.).

Such are some of the chief peculiar structures which rocks exhibit.

UNSTRATIFIED ROCKS (IGNEOUS, BASIC).

[Note.—All the minerals mentioned in describing these rocks are described under Section II., with which the student is supposed to be familiar already.]

Professor Seeley, the eminent geologist, has divided the unstratified—or, as he terms them, the crystalline and igneous—rocks into the following classes:—[1]

1. The family of perfectly crystallised quartz-orthoclase rocks.
2. The felsyte and rhyolyte series of imperfectly crystallised granitic rocks.
3. The family of quartzless orthoclase rocks.
4. The family of quartz-bearing plagioclase rocks.
5. The family of quartzless plagioclase rocks.

It will be seen from this that the classification depends upon the predominance of either orthoclase (potash feldspar) or plagioclase (soda and lime feldspars); and, further, that the classes are divided into those rocks which have quartz and those which have none, or very little.

Geologists are greatly at variance on the classification to be adopted, but in addition to the undoubted standing of the authority quoted, the classification is, as all should be, exceedingly simple. No further apology is needed for its use.

[1] Phillips' *Manual of Geology* (Seeley).

1. *The Family of Perfectly Crystallised Quartz-Orthoclase Rocks.*

Name	Typical Composition
Granyte	Quartz, orthoclase, mica.
Syenitic granyte . . .	Quartz, orthoclase, mica, hornblende.
Protogine	Quartz, orthoclase, mica, talc, or chlorite.
Luxulianyte (schorl granyte)	Quartz, orthoclase, mica, tourmaline.
Aplyte (granityte) . . .	Quartz, orthoclase.
Granulyte	Orthoclase, mica.
Greisen	Mica, quartz.

The composition given in the tables is that of a typical species; rarely, however, are any rocks composed of their typical minerals. In granyte, for example, plagioclase feldspars are frequently present, and in the variety 'greisen' the feldspars are absent, while the mica is of various kinds, biotite, muscovite, or pulogopite.

Granyte and the granyte family are easily recognised and widely known; they are all visibly crystalline, the feldspar crystals varying from minute flakes (when the granyte cooled quickly and under great pressure) up to crystals many inches in length, when the conditions under which the consolidation took place were exactly the reverse. The quartz crystals frequently contain bubbles of liquid and CO_2 in cavities rarely visible to the naked eye.

Granytes are *metamorphic* and *vulcanic* rocks; that is to say, they have been formed by the influence of heat or movement, or both, upon already existent strata. The chemical composition of granyte agrees very nearly with that of some sandstones and clays, and there seems to be now no reason to doubt that granytes are merely altered portions of these strata—portions which have been subjected to intense heat, movement, and pressure.

Granyte occurs either as intrusive veins or in hills and masses varying from a small boss up to a large mountain range extending for many miles. It has been forced up from beneath the earth's solid crust in a pasty, moist condition, from which, under varying circumstances, it has consolidated and crystallised.

Granyte is always newer or younger than the rock it fissures

or overlies. It occurs in all geological periods, and in one form or another in every quarter of the globe. It contains gold and silver in itself, and ores of many metals—gold and tin (the latter in particular near to luxulianyte or schorl granyte), for example, in veins penetrating it. Granyte passes into *gneiss* by pressure; the latter is a granyte in which the rock has assumed a schistose structure, the component minerals having arranged themselves more or less in layers.

The decomposition of granyte resulting in the dissolution of the feldspars gives rise to a friable rock called 'arkose.' 'Kaolin,' a fine-grained clay of various degrees of purity and colour, from white to reddish, is the resulting mineral from the decomposition of the feldspar. Kaolin is valuable for china and porcelain manufactures.

Syenitic-granyte is a hard compact granyte of a dark greenish colour, the colour resulting from the presence of the mineral hornblende, which partly replaces the mica.

Protogine is a softish granyte containing pale green stains of chlorite or blotches of talc.

Luxulianyte is a softish flesh-coloured granyte in which the mica is partly replaced by the impure subsilicate of alumina, tourmaline (or schorl).

Aplyte-granityte is a hard granyte in which the mica is very scarce or entirely absent.

Granulyte is a granyte, often soft and easily decomposed, in which the quartz is very scarce or entirely absent.

Greisen is a foliated soft granyte in which the feldspars are very scarce or absent. Greisen is probably the chief original rock from which mica-schist has resulted.

The conditions under which the granyte paste crystallised were not always the same.

On page 84 we have seen that where the granyte consolidated slowly and perhaps under low pressure the separation and growth of the crystals of the various minerals were able to proceed advantageously; but where the pressure was great and the cooling rapid a large portion of the paste remained as a paste, in which the crystals were very small at the time of consolidation. *Felsyte* is the generic name given to this imperfectly crystallised paste.

2. *The Felsyte and Rhyolyte Series of Imperfectly Crystallised Granitic Rocks.*

Name	Typical Composition
Granyte porphyry . . .	Compact felsyte with crystals of quartz, feldspar, mica, or chlorite.
Elvanyte quartz porphyry .	The same with no mica or chlorite.
Felsyte euryte . . .	Compact felsyte occasionally with crystals of quartz and feldspar.
Pitchstone	A glassy felsyte with microlites and sometimes crystals of sanidine, quartz, and mica.
Rhyolyte or quartz-trachyte .	Compact felsyte with quartz crystals, and occasionally with sanidine and mica.
Perlyte	A grey enamel-like rock with grains like pearls. Sometimes quartz, sanidine, and mica.
Obsidian	Black, brown, red, or green volcanic glass.
Pumice-stone . . .	An obsidian frothed by the bursting of numbers of steam-filled cavities.

Granyte-porphyry is a granyte in which, through some influence imperfectly understood, large isolated crystals of the granyte-forming minerals separated themselves from the mass of felsyte, which remained more or less in a pasty magma.

Elvanyte or *quartz-porphyry* bears the same relation to aplyte or granityte as granyte-porphyry does to granyte. It is a hard compact rock.

Felsyte or *euryte*, a many-coloured rock from grey and bluish to brown and red; compact and very hard. It is a rapidly cooled granitic paste.

Pitchstone, a dark glassy rock with numbers of small crystals of glassy feldspar. It is a glassy felsyte which has cooled rapidly or quite suddenly.

Rhyolyte or quartz-trachyte.—Rhyolytes are of many colours and textures, breaking with a rough fracture. They frequently exhibit wavy lines of structure (*fluxion*), caused by the arrangement in lines or layers of mineral aggregates or coloured obsidian. They contain a large amount of quartz, which has resulted from the high proportion of silica, all of which has not been required to complete the feldspar crystals.

Perlyte is a rapidly cooled rhyolyte.

Obsidian, true volcanic glass. It is always of some dark

colour, looking and breaking like dark bottle-glass. It has evidently cooled most rapidly, and not improbably quite suddenly.

Pumice-stone, a light spongy, fair-coloured rock which floats on water. It is a volcanic product, and is ejected in great quantities from active volcanoes. The cavities with which it is crowded are the boundary walls, so to speak, of bubbles of steam and air, of which the rock was full at the time of its ejection, and which subsequently exploded.

This family of rocks is partly volcanic and partly vulcanic (see page 121, Section IV.).

Of the former, obsidian and pumice are found in connection with extinct and active volcanoes, as round Etna, Hecla, Vesuvius, and Teneriffe. They are both unmistakable.

Rhyolytes, which are also volcanic, are widely distributed both in the Old and the New World, being well developed in Auvergne, Iceland, North America, and New Zealand. They occur spread out in wide sheets and thick masses, the fluxion structure often showing the direction and even the rapidity of their flowing from the source of outpouring.

Felsyte is an imperfectly crystallised vulcanic rock. Like rhyolyte, of which it may be but an ancient species, it has a very wide distribution, occurring, like granyte, both in masses and dykes (see page 89).

Mineral veins are frequently found in connection with this family of rocks.

3. *The Family of Quartzless Orthoclase Rocks.*

Name	Typical Composition
Syenyte .	Orthoclase and hornblende with oligoclase, mica, nepheline, and augite. When with zircon called zircon-syenyte.
Porphyryte .	A felsyte matrix with crystals of orthoclase or oligoclase forming feldspar-porphyry. With mica forming mica-porphyry, with hornblende forming hornblende-porphyry.
Trachyte .	Granular sanidine with crystals of magnesia-mica, hornblende, and sanidine.
Minette. .	Granular mixture of biotite, orthoclase, nepheline, and sodalite.
Phonolyte .	Compact sanidine, nepheline, hornblende, and titanite with crystals of sanidine.

Syenyte.—A vulcanic rock closely related to granyte. It is generally a greenish and flesh-coloured rock from the

colours induced in it by its chief typical minerals, orthoclase and hornblende. Sometimes syenyte contains augite (augite-syenyte), sometimes mica (mica-syenyte). Zircon-syenyte is rare. It occurs chiefly in intrusive dykes.

Porphyryte.—A volcanic rock, close-grained, and breaking with an even fracture. It is formed almost entirely of feldspar, with some magnetite. It is known by various names according to the development of certain minerals; mica-porphyry has much mica; hornblende-porphyry much hornblende, &c. Porphyryte was largely outpoured during the Carboniferous age, and would appear to be an imperfectly crystallised lava. It exists chiefly in wide-spreading sheets.

Trachyte.—A rock of various colours, hard, but brittle, and with a rough fracture. It is the volcanic representative of syenyte. It was originally poured out as a thick, viscous (i.e. with a consistency like treacle) lava stream. Sanidine is always well represented, and the minerals hornblende, augite, apatite, magnetite, and titanite are often present.

Minette.—A vulcanic rock. It is a dark-coloured felsitic rock, with considerable quantities of biotite. It occurs chiefly in dykes and intrusive veins.

Phonolyte.—Called also *clinkstone*. A hard compact rock which rings under the hammer when struck, and turns white by weathering. It is a nepheline-trachyte. Large and well-developed crystals of amphibole occur in this rock, and zeolites often occur in the cavities existing in the mass. Both sanidine and nepheline are beautifully clear and well developed. It is a widely distributed rock, occurring in sheets and masses round many extinct volcanoes. It is well developed in the Auvergne and in North America, also in Teneriffe.

This family of rocks is recognised by the absence of quartz, and by the well-defined crystals of sanidine. The rocks of this group appear in both masses and dykes in many districts which have been greatly disturbed, and have been largely instrumental in disrupting, tilting, and fissuring the strata in which they occur.

Quartz-dioryte is a very tough greyish to greenish white rock, rich in silica. It varies in texture from a fine-grained compact rock to a very coarse porphyritic one. It contains

various accessory minerals, more particularly alluded to in the description of the next family. It is a *metamorphic* or *vulcanic* rock, and occurs in veins. *Tonalyte* is a variety in which mica and quartz are well developed.

4. *The Family of Quartz-bearing Plagioclase Rocks.*

Name	Typical Composition
Quartz-dioryte . . .	Quartz, plagioclase, hornblende.
Quartz-propylyte . . .	A minutely crystalline paste of quartz, oligoclase, and hornblende, with larger crystals of the same and titanite.
Dacyte or quartz-andesyte .	Feldspar, hornblende, quartz, small crystals of oligoclase, sanidine, and magnetite.
Quartz-doleryte . . .	A minutely crystalline paste of quartz, plagioclase, augite, and olivine.

Quartz-propylyte.—A vulcanic greyish green rock, consisting of a paste with large crystals of dark green hornblende and white or light green oligoclase. It occurs in large masses, having probably been ejected through fissures. It is tough, and fractures unevenly.

Dacyte (*quartz-andesyte*).—Dacytes are well developed in both the Old and New Worlds. They are andesytes (see page 94) with quartz, hornblende, and ruby-coloured mica often being present. Dull greyish green in colour; compact, but not hard. They are of volcanic origin.

Quartz-doleryte.—Belongs to the group of rocks to which the name 'Trap' has been given. Quartz-doleryte is a hard, compact, dark-coloured rock, somewhat richer in silica than doleryte (see page 95). It is an eruptive rock, occurring both in veins and masses.

The rocks in this family are not far removed from those following. An excess of silica has, however, resulted in the formation of quartz-crystals, the occurrence of which serves to distinguish them from their related group. It is well to note that quartz-propylyte is often associated with silver and lead lodes.

It will be seen that this family is subdivided into two classes: those which have the plagioclase feldspar, *oligoclase*,

as the chief feldspathic constituent, and those which have the plagioclase feldspar, *labradorite*, as the predominant one.

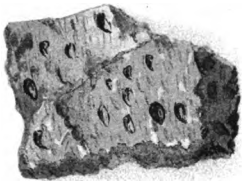
5. *The Family of Quartz-less Plagioclase Rocks.*

Name	Typical Composition
	With oligoclase as the chief feldspar.
Dioryte	Oligoclase and hornblende.
Andesyte	Andesite, with crystals of augite or hornblende biotite and magnetite.
	With labradorite as the chief feldspar.
Gabbro	Labradorite, diallage, or pyroxene.
Doleryte	Labradorite, augite, olivine.
Basalt	Labradorite and augite, with olivine and titanite.
Diabase	Like doleryte, but contains some chlorite.

Dioryte.—A widely distributed and well-known rock, although diabase, doleryte, and even basalt are frequently mistaken for it. It is a fine-grained, compact, and very tough rock of various shades of colour, from light grey and green to dark greenish black. In addition to its typical constituents it contains often labradorite, orthoclase, apatite, magnetite, and pyrite. When quartz is present it is known as *quartz-dioryte*. The hornblende is easily recognised in the form of small needles and columns, and the feldspar is more often flesh-coloured than white. It has a structure like syenyte, and probably consolidated under similar conditions. It is an eruptive vulcanic rock, and occurs chiefly in wide dykes and fissures.

Orbicular-dioryte shows ring-like markings, and contains much anorthite.

Andesyte.—A hard compact rock, its typical composition with a mixture of andesite, with either augite or hornblende. Accessory minerals are biotite, magnetite, titanite, and garnets. *Augite-andesyte* is a dark grey (nearly black) rock in which the dark-coloured crystals of augite may frequently be detected. *Hornblende-andesyte* is a pale grey compact rock in which the dark green hornblende crystals occur in small columnar forms. Occasionally the hornblende appears surrounded by pale green stains, pointing to its alteration into chlorite. Andesytes are widely distributed vulcanic



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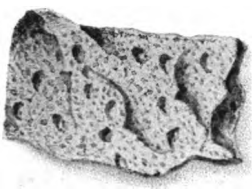

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1. PUMICE. LIPARI ISLES.
2. SYENYTE. LEICESTER.
3. HORNBLENDE PORPHYRYTE. SAXONY.
4. TRACHYTE. RHINE.
5. DACYTE. HUNGARY.

rocks, occurring chiefly in wide sheets, which have been poured out from dykes and fissures.

Gabbro.—A hard crystalline rock. In addition to its typical minerals, it frequently contains magnetite and mica. With olivine, it is known as an *olivine-gabbro.* The feldspar, anorthite, sometimes replaces the labradorite. It varies in colour from dark grey and blackish to a brown rusty red, and bright spangles of mica are not uncommon. *Hypersthenyte* is a closely related rock. Gabbro is a vulcanic rock occurring in intrusive dykes and sheets. It is common in many mineral districts, and is often associated with serpentine.

Doleryte.—A very hard, compact, visibly crystalline rock. It varies in colour, which is always dark, from greyish and bluish to green black and brown black. It is in reality a crystallised variety of basalt, from which it is but slightly separated. In addition to its typical mineral constituents, it often contains olivine, magnetite, and apatite.

Basalt.—A compact, minutely crystalline mixture of labradorite and augite, with olivine, magnetite, and titanite. The olivine is a very common mineral, appearing in the matrix like small pieces of oily-green stained glass. Basalt is intensely hard, of various dark shades of colour, from grey to black. It occurs in many of the geological periods, and has been at all times an active eruptive rock. It has been poured forth as lava-streams from volcanic vents and fissures, and occurs in widespreading sheets. Basalt is often vesicular, and assumes many curious columnar forms.

Diabase.—An ancient doleryte or crystalline basalt, occurring in rocks of Primary age. It is a dark compact rock, intermediate in appearance between doleryte and basalt. It is frequently to be recognised by the light green patches of chlorite, arising from the decomposition of the olivine.

Of this family, dioryte, andesyte, and propylyte are typical members of what are called the *greenstone* class of rocks; while doleryte, basalt, and diabase are typical members of the *trap* or *trappean* series. They are all widely distributed upon the earth, and one or other of the family is nearly sure to be present in any disturbed district. Dioryte and andesyte are frequently found in connection with mineral

and coal deposits, which latter are often violently faulted by their agency.

Gabbro is a common intrusive rock among veins of copper, tin, and other metals.

Basalt and its relations, doleryte and diabase, occur chiefly in widespreading sheets and beds, the first-named occurring at Staffa, the Giant's Causeway, and in Germany in immense columnar masses (fig. 20). They are essentially volcanic rocks, and can be traced to the cones of the volcanoes from which they were poured forth with little difficulty. Basalt is the rock enclosing the great diamondiferous deposits at Kimberley, in South Africa.

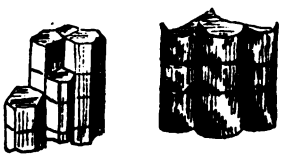

Fig. 20.—Basalt Columns.

Such are the chief families of these unstratified, igneous, or basic rocks. The varieties of each rock are well-nigh endless in chemical constitution, in appearance, and occurrence. An intimate knowledge of them is to be gained only after much study, but the types described should assist the student to recognise and place in its proper class any of the above which he may find.

In connection with the above the following may also be described:—

Breccia.—A rock formed out of the angular fragments ejected from a volcano. It occurs chiefly under water in the vicinity of active and extinct volcanoes.

Fig. 21.

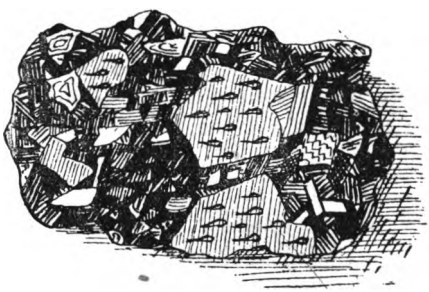

Fig. 22.—Breccia.

Tufa.—A similar rock, but with the fragments smaller.

Pozzuolana.—A light-coloured powdery tufa, found near Rome. It is used for making hydraulic cement.

Schists.

The schists are a remarkable group of rocks, representing as they do a largely distributed series, whose original physical characteristics have been altered and in some cases entirely obliterated. Although among the schists there are a few stratified rocks (argillyte, clay-slate, &c.), they are for the most part altered igneous rocks. They are nearly always tilted at high angles, and are contorted and crumpled into most fantastic shapes. They consist chiefly of layers of quartz and some other mineral or minerals, garnets being very common in many. The arrangement in layers (*foliation, schistose structure*) has been induced in these rocks by *metamorphism* (see pages 85, 86, and 136, Section IV.). Gneiss, for example, is a schistose granyte, from which it differs in appearance but not in composition.

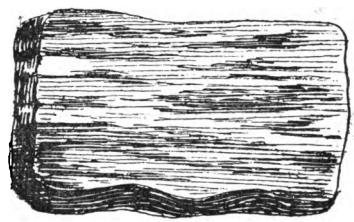

Fig. 23.—Schist.

Chief among the schists are the following:—

Mica schist.—A foliated arrangement of quartz and mica; probably a schistose greisen, granyte, or dioryte, the mica being derived probably from the decomposition of the feldspar. It is very often found in Archæan rocks.

Chlorite schist.—A foliated arrangement of quartz and chlorite, containing also magnetite and mica. It is greenish in colour, has a greasy feel, and is a common companion of gneiss.

Hornblende schist.—A foliated arrangement of quartz and hornblende, sometimes with orthoclase. It is dark green in colour, and is a schistose structure of amphibolyte or massive hornblende.

Talcose schist.—An uncommon arrangement of quartz and talc in layers. It is light green in colour, very greasy to touch, and occurs only in isolated beds.

Hydromica schist.—Commonly called *talcose schist.* It is a chloritic-mica schist, *with water.*

Soapstone steatyte.—A highly compressed, schistose, massive talc; often impure. It is employed for the carving of ornaments and images in some countries. From the fine qualities *French chalk* is obtained.

All these schists are commonly found flanking hills and around centres of great volcanic disturbance. They are common in most mineral districts.

SERPENTINE.

Serpentine is a yellow, greenish yellow, green, or mottled rock, greasy to the touch, and easily scratched with a knife. It has resulted from the alteration and partial decomposition of olivine, the silicate of magnesia contained in this mineral having become hydrated (i.e. watered or moistened) and altered. It is a common rock in the neighbourhood of olivine-bearing rocks, and is often associated with gabbro. It is found in thick beds and masses.

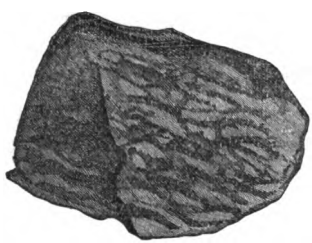

Fig. 24.

Noble serpentine is of a rich oil-green colour, and is employed for artistic ornaments. *Common serpentine*, of various mottled-soapy colours, is used for ornaments, inlaid-mosaic work, and for various architectural purposes.

STRATIFIED ROCKS (SEDIMENTARY, AQUEOUS).

We will now consider briefly the various kinds of rocks which do not owe their origin to igneous agency. As explained on page 84, we have included under this section all those rocks which owe their origin to the various modifying causes which have been and are at work upon the earth, so that we must include under this heading those which have been formed by the agency of plant and animal life existing

in air and sea and on land, and also those which have, *after deposition*, been metamorphosed. These latter subdivisions may or may not have been originally stratified, but they are at least more nearly related to the Stratified-sedimentary-aqueous series than to the Unstratified-igneous-schistose group.

Silt.—The name given to the fine sediment which gathers in quiet waters, round corners, and in the hollow places of rivers, lakes, estuaries, and seas.

Clay.—An exceedingly fine-grained, moist rock formed of minute particles. It is the result of the decay of various aluminous silicates, and, except when powdery, always contains water. When quite pure it is white, but is generally coloured red, blue, green, grey, brown, &c., from the presence of various impurities.

Fireclay.—A clay found beneath layers or beds of ancient vegetation (coal-lignite), where it represents the original soil upon which the vegetation grew. It can be heated to a white heat without fusing, and is largely employed for the linings of furnaces and stoves.

Marl.—A general term used for all compounds of lime and clay. When clay predominates they are called *clay marls*; when lime predominates, *lime marls* or *marl clays*. They are compact rocks, breaking with a conchoidal fracture. They are of various colours, liver-brown and red chiefly, and frequently contain nodules of lime-carbonate.

Mudstone.—Massive consolidated clay. It does not split into layers or laminæ.

Shale.—Consolidated clay which splits into thin parallel laminæ, which represent, probably, various cessations and directions of the original deposition. Shale was probably deposited as *silt* in the quieter waters of rivers, lakes, estuaries, and seas. Of various colours and shades. Shales frequently contain fossils, which tell of the conditions existing at the time the silt was laid down.

Slate.—An exceedingly hard, consolidated shale. It splits off into laminæ, which have, however, nothing to do with the original planes of deposit, but are the result of *cleavage* (see page 136, Section IV.). Slates are grey, blue, green, and

purplish in colour; sometimes black. They are consolidated clays of the very earliest stratified deposits. *Roofing* slate is a very compact kind, which splits into very fine and even laminæ.

Chiastolite slate (*chiastos*, a cross) contains small cross-like crystals of the mineral *chiastolite*, in veins, and scattered through the rock.

Phyllite, argillyte.—Slates in which more or less mica is present. The flakes of this mineral lie in layers along the cleavage planes, and result from the action of metamorphism upon the minerals of which the rock is composed.

All classes of slates are widely distributed in the world.

Sand.—Minute particles, from microscopic grains up to those as large as a pea, of quartzose or other hard siliceous rocks. They are generally round and water-worn. Sand has been formed by the disintegrating action of wind, atmosphere, or water upon the exposed surfaces of rocks. Sand is of many colours, according to the nature and state of the minerals forming the rock from which it is derived.

Gravel.—Water-worn débris. It is merely a larger sand. It consists chiefly of fragments of hard siliceous and quartzose rocks, the débris of the softer rocks being pounded more readily into silt. River-gravel is rounder than sea-gravel or beach pebbles.

Conglomerate.—Gravel which has become consolidated into a compact mass, the pebbles having been cemented together by some cementing material, such as silica, iron peroxide, or lime carbonate. Quartz conglomerates, or those containing quartz pebbles, have in many cases—notably at Witwatersrandt, Transvaal—been highly auriferous. Subangular pebbles, and even quite angular débris, is also found cemented into solid masses, when it is termed *aqueous-breccia.* The cementing has been brought about probably by percolating water holding the cementing agent in chemical solution, assisted by great pressure of over-burden.

Fig. 25.—Conglomerate.

Sandstone.—Consolidated sand. It bears the same relation to sand as conglomerate does to gravel, and has resulted from similar cementing action. Sandstones are of many colours: iron peroxide colours them yellow, brown, and red; glauconite colours them green; while calcareous sandstones are white and grey.

Sandstones are most widely distributed, being probably the most common of rocks.

Micaceous-sandstone is a variety containing mica, usually in small bright flakes. The mica is almost always Muscovite.

Quartzose-sandstone is a variety in which largish grains of quartz are prominent. Very hard usually.

Grit.—A variety of sandstone more common in the older than in the later formations. It is composed of coarse angular grains of quartz, which point to its arrangement in strata and consolidation into stone within a short space of time after its separation from its parent rock.

Greywacke.—A name formerly applied to the coarser kinds of silurian and other ancient deposits. It is a compact mass of angular and subangular fragments of quartz and other minerals. It is very tough.

Quartzyte.—A compact, exceedingly hard rock, composed of granular quartz. It is a *metamorphic sandstone*, and not infrequently contains relics of organic life. It occurs in interstratified beds.

Flagstone.—A sandy-slate or a slaty-sandstone. It is quarried from some of the older geological systems in large flags suitable for paving.

Loess.—A sandy light-coloured clay. It is dry and wind-driven, and is sometimes so compact as to be cut into caves and cells fit for human habitation.

Till.—A local name given to the glacial-age deposit, boulder-clay.

Earths.—*Fuller's-earth* is a fine-grained argillaceous powder from the Bathonian stage of the jurassic system (see page 181, Section IV.). *Infusorial earth* (diatom-earth, Tripoli earth) is a powder formed of the minute frustules of diatom plants. *Brick-earth* is the name given to particles of soil and sub-soil washed down from higher to lower levels.

All the above have been formed by various processes of sedimentation. The following are due to the action of chemical precipitation.

Limestone.—A greyish, yellowish, or brownish rock of various degrees of purity. It is, when pure, formed of calcium carbonate which has been precipitated from waters holding lime carbonate in solution.

Stalactites are pendent, and *stalagmites* upright limestone needles. They may be of any size, from a mere thread a fraction of an inch in length up to solid pillars many feet in length and diameter. Compact pure limestone is a matrix of calcite crystals.

Marble. A metamorphic rock.—It is the outcome of contact or regional metamorphism (see page 136, Section IV.) upon limestone. It is, when quite pure, of a beautiful sugary white, but it is often mottled and veined by various impurities.

Calcareous tufa (*travertine*).—A lime-carbonate deposit, formed by springs issuing from limestone or any rock abounding in lime. It is of various colours according to the purity of its composition, and is of all degrees of hardness, from a crumbling powder up to a hard solid rock. It often contains fossils, and is sometimes finely laminated.

Fig. 26.—Pisolite.

Oolite, pisolite (see page 87).—Oolite is a limestone formed of rounded grains, looking like the roe of a fish. In pisolite the grains are as large as a pea. Each grain is composed of successive layers of calcium carbonate.

Hydraulic limestone.—Contains a small proportion of clay, and has the property of hardening under water after being calcined or burnt. It is generally artificially prepared for commerce.

Limestones are widely distributed rocks; they can be readily recognised by the ease with which they can be scratched, and by their effervescence and solubility in acids.

Dolomyte (*magnesian limestone*).—A dirty greyish or yellowish rock. When pure it consists of 54 per cent. of magnesium carbonate and 46 per cent. of calcium carbonate.

It is compact, but often assumes globular or other concretionary forms. It is harder than limestone, and does not effervesce so freely in acids. When metamorphosed it makes an impure marble, frequently showing veins of iron oxide running through the ground mass. It is not such a widely distributed rock as limestone, but probably was originally a limestone, the magnesium carbonate subsequently replacing in part the calcium carbonate.

Fig. 27.—Dolomite.

Quartz.—The mineral silica (see page 65, Section II.) occurs often in veins, sheets, and dykes, more especially in the older strata. It has in part been deposited on the walls and floors of cavities and strata by chemical precipitation, condensation, or sublimation. It is of various colours, according to the impurities contained, from pure white to grey, blue, and even black.

Siliceous sinter (*sintern*, to drop) is a white, grey, light pink, or blue powdery deposit of almost pure silica, which is being, and has been, deposited around hot geysers and mineral springs. It is a common rock in Iceland, North America, and New Zealand.

The following rocks owe their origin to the varied action of plant and animal life:—

Limestone.—Many animals have the power of secreting or taking up large quantities of lime in their harder parts. These harder parts are best constituted for fossilisation, so that among rocks of organic origin calcium-carbonate is the most common substance.

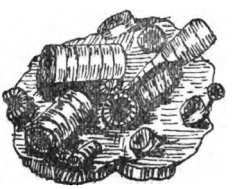

Fig. 28.—Encrinital Limestone.

Crinoidal limestone is composed of the calcareous remains of crinoids, shells, corals, and other marine life. The weathering of a surface of crinoidal limestone will often bring out its structure; the fossilised remains, being better able to withstand the weathering, stand out clearly against the ground mass of the rock (fig. 28).

Chalk.—A soft white calcareous rock formed entirely of

the crumbled remains of Foraminifera and other marine fossils (see page 186, Section IV.). Chalk is very easily recognised, and always denotes a marine origin for the strata it composes.

Shell-marl.—A soft white crumbling calcareous rock. It is the freshwater equivalent of true chalk. It contains perfect and fractured freshwater fossils.

Coral.—A rock formed of the accumulated remains of the coral insect. These creatures secrete within their gelatinous body a hard skeleton of carbonate of lime; when the insect dies this skeleton is added either to a similar mass already existing, or is left upon the submerged rock upon which it lived. In process of time very large accumulations are formed, many of the islands in the warmer latitudes of the world being entirely composed of the calcareous skeletons of these insects.

Nullipore-rock.—A calcareous sand-rock formed by the action of rainwater and other moisture upon the carbonate of lime grains secreted by the nullipore seaweed. These grains are gradually congregated on the sea shore upon which the dead nullipore branches are thrown up.

Peat.—A dark brown mass of compressed marshy vegetation. It is used as fuel.

Lignite, brown coal.—An intermediate stage between peat and coal. It retains the forms of its component vegetation (see page 82, Section II.).

Coal.—A brittle black rock. It is formed of compact and mineralised vegetation, and is found lying on beds of fireclay (page 99) which represents the soil upon which the vegetation grew (see also page 81, Section II.).

Guano.—A whitish or light brownish powdery deposit formed of the droppings of sea birds. It is used as a manure, and is found on the coasts of South America and East Africa, as well as elsewhere, on small islands and rocky headlands.

As with the unstratified or igneous rocks, so with these; the chief species only have been described, but it is believed that under this section sufficient has been written to materially assist the student or explorer in properly classifying rocks which he may meet with in the course of his journeys.

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C. Wilson-Moore, del.

1. DIORYTE (GREENSTONE). CORNWALL.
2. AUGITE-ANDESYTE. NASSAU.
3. RED GABBRO. CORNWALL.
4. AMYGDALOIDAL-DOLERYTE. THURINGIA.
5. BASALT. EDINBURGH.

SECTION IV

GEOLOGY

CHAPTER I

Modifying Causes at Work upon the Earth

Geology is the science which treats of the structure, composition, and successive modifications of the accessible portions of the crust of the earth. In a fuller sense, geology is the science which investigates and teaches the ancient natural history of the planet we inhabit, in what succession and under what conditions inorganic and organic matter and life appeared; it measures, by comparison with existing data, the successive revolutions which the earth has undergone, and furnishes man not only with the complete mechanical, physical, and chemical phenomena of itself, but exhibits to him certain guide-marks which show him a way to reach and unravel the secret treasures of nature.

Geology, like petrology, is a science of observation, so that too much stress cannot be laid upon the advice that all prospectors and miners should make themselves personally and practically acquainted with the various phenomena exhibited by rocks and rock-systems with which they may come in contact.

To prospectors and miners a sound elementary knowledge of geology is of the highest practical importance. The former will in countless instances find himself saved many a weary toil up hill or down ravine in what would have been a fruitless search for minerals; he will thank his knowledge of geology ofttimes that it saved him toil and money on a vein which 'petered' out a few feet from surface. The miner will often

acknowledge with gratitude the recovery of his lost lode to his knowledge of the laws which govern geological movements, and both, if interested in their work, will find pleasure and profit in unravelling the problems which will constantly present themselves.

For the purposes of this work only the outlines of this most interesting and valuable science are needed. The mere skeleton will therefore be given in this section, the student being advised to fill up the figure from one or other of the advanced manuals on geology. (See Appendix.)

The first great law which geology teaches is, that the crust and surface of the earth are undergoing constant change; the first investigation on our part, therefore, must be the causes which bring about these constant changes, and the effects produced by them.

These modifying causes, as we will call them, may be classified as follows:

Modifications produced by the action of—

1. Atmosphere.
2. Running Water.
3. Springs.
4. Lakes.
5. The Sea.
6. Ice and Snow.
7. Volcanic Action.
8. Vulcanic Action.
9. Plants and Animals.

1. *Modifications produced by atmospheric action.*—All must have noticed the frequent decay of stones employed in our buildings; in some cases a smoothly dressed sandstone splits off into thin flakes, or crumbles slowly away; in others a once polished granyte surface becomes roughened; or again, a limestone wall becomes pitted with small holes. These processes of decay are called 'weathering,' and are brought about by the action of the atmosphere and its constituents upon the surfaces exposed to its influence. As in art, so in nature, no one can have failed to notice the crumbling away or disintegration of exposed rock surfaces.

The change in temperature day by day aids in this destruction. A rock heated by the sun's rays by day expands considerably, while it contracts just as much when cooled by the night air; this ever-recurring expansion and contraction causes an unequal strain upon the rock, the outer particles of which in time become separated, and, crumbling or peeling away, a new surface is exposed to the same destructive action.

A similar effect is produced by the alternate soaking and drying of rock-surfaces by rain, or moisture and sunshine; the various particles are apt under this action to loosen and pulverise.

Rain, too, frequently contains some chemical impurities which it has gathered in its descent, and these act *chemically* upon the rocks, in some cases consolidating, but in the great majority disintegrating them.

Soil and rocks which are saturated by moisture are liable to another kind of disintegration. When their temperature falls below 32° F. the moisture they contain freezes and expands (see Section I., page 14), pushing the adjacent particles asunder with irresistible force; by-and-by the ice melts, and, turning to water, the sundered portions are liberated, falling ultimately to lower levels, while much of the exposed surface is turned into soft material. This action is particularly prevalent in those places where the temperature varies greatly above and below 32° F., such as countries within the polar circles and the tops of snow-capped mountains.

Wind, especially in dry and sandy countries, is a powerful agent in the alteration of the earth's surface. In South Africa, for example, on many parts of the coast huge deposits of sand may be seen; in some places they climb far up the hills, here partially and there entirely, burying the vegetation; in others they may be watched year by year creeping up between the hills, converting green valleys into dry and dreary wastes.

In fig. 29 a typical view is given in which the various actions described above may be traced.

At the top of the cliffs the rock is seen to be disintegrated, and weathered first into *soil* and then *subsoil* by the action of rain, frost, or snow; at the bottom of the cliff is a slope of

talus, composed of the washed-down and splintered fragments from the exposed face above; while in the distance wind-driven sand hills, or *dunes*, as they are called, point to the action of

FIG. 29.

A. Soil. B. Subsoil. C. Unaltered Rock. D. Talus. E. Sand Dunes.

swift-moving atmosphere or wind. Thus it will be readily seen that the various states of the atmosphere are active agents in the alteration of the appearance of the earth's surface.

2. *Modifications produced by the action of running water.*—These may be conveniently divided into two kinds, the mechanical and the chemical.

In countries where the rainfall is concentrated within a few short periods, and where the amount precipitated upon the earth is more or less considerable, within the space of an hour or so, the mechanical action of running water is very marked. A slight shower of rain will remove all the loose particles of sand and dust, and, carrying them by means of the little channels which it forms to the nearest brook or river, will leave the surface exposed to fresh atmospheric action; a heavier shower will cut deeper channels, swirling coarse sand or gravel in the same direction; while a violent downpour will materially enlarge the channels already made, and, joining the turbulent river, will discharge into it huge quantities of sand, gravel, and even large boulders. In the bed of many a mountain creek one can study the action of running water to advantage; at the top of the creek there are large angular blocks of stone which have become detached from the overhanging crags; further down the creek the blocks become more rounded and waterworn, but they can still be recognised as having come from strata far up among the hills; going further down still into the widened and less steep reaches of the creek, which has now become a river, the boulders give place to wide stretches of gravel and sand, the current, here much less rapid, only moving them in times of flood or turbulence. From this the prospector may learn the lesson that by following up the detached rocks in the bed of a creek or river he may arrive at the original matrix or home of any material which he may chance to come across in the bed of the river. Every river, brook, or runlet is, with varying degrees of intensity, performing its share in the alteration of the earth's surface; and by means of the records they leave are placing guide-marks for man in the accessible valleys whereby he may trace the treasures of nature to their home in the difficultly accessible mountains.

It is obvious, however, that the mere fact of a river transporting large quantities of roughened blocks, sand, and silt along its course must be productive of another kind of change.

The grinding action which reduces the angular blocks into waterworn boulders, gravel, sand, and silt has a similar effect, though in a less marked degree, upon the bed and sides of the river itself. In the course of time the bed of the river becomes deeper and deeper, until from being but a few feet lower than the surrounding country, it appears as a deep precipitous ravine. By carefully observing the marks left upon the sides of such a ravine one can easily see the successive levels which the bed of a river has assumed. Circular *pot-holes*, as they are termed, caused by the rotation of stones and gravels in one part of the bed of a river, may also be often observed; in many places they are far above the present bed, thus showing in a most striking manner the difference of level which the river has assumed. Again, the successive levels of a river bed may be observed in its lowest reaches, where wide river terraces which represent the old levels spread out on either side of the present banks. Sometimes tier upon tier of these terraces may be seen, each rising but a few feet above the other, and this feature is often noticed in dry countries.

Another point, the result of the action of running water, is worthy the attention of prospectors. One can trace with certainty the direction in which a stream which has deposited alluvium has flowed.

The rounded and oblong stones in the bed of a river may frequently be seen piled one upon the top of another, with the elevated portion of the longer axis pointing away from or down the course of the stream. Again, when cutting through a series of alluvium strata it will be noticed that they are not always horizontal layers, some being more or less inclined, as is shown in fig. 31. By comparing these inclined strata with the direction in which the stones in them are lying (as explained above), it will be seen that the downward inclination is in the direction of what had been the flow of the stream.

Fig. 30.

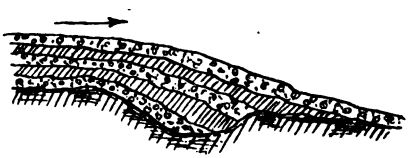


Fig. 31.

When the hollow which existed had been filled up, the deposition of strata had proceeded with regularity as before.

It is evident from what has been said that running water has a powerful mechanical influence upon the surface of the land, transporting and rearranging material in ever varying manner. The records left are easy of observation, and are of practical use in leading to the discovery of minerals in difficultly accessible regions (see page 246, Section VI.).

But the chemical action of running water is also an important factor in the changes that have taken and are taking place upon the earth's surface.

FIG. 32.

Rain in passing through the air to the earth absorbs certain impurities, even from the purest atmosphere, hardly ever reaching the earth as the pure compound of oxygen and hydrogen which it was as a cloud (see page 14, Section I.). Among other impurities it gathers ammonia and carbon dioxide; armed with these, it proceeds to attack and corrode whatever rocks it falls upon; the rain also, passing into the soil, absorbs animal and vegetable acids therein, thus becoming more strengthened for chemical erosion. Some kinds of rocks are more liable to this erosion than others, limestone being peculiarly so. Large quantities of carbonate of lime are dissolved out of this rock and are conveyed by rivers to the

sea, where the shells of marine animals are largely composed of it. Sulphate of lime (gypsum) is another impurity of river water, its presence therein, together with carbonate of lime, being the cause of water becoming what is called 'hard.'

The record of the chemical action of running water upon rocks may be studied in any district where limestone occurs as the bed-rock. The upper part of the bank will be seen weathered but not corroded, while lower down, where the water of the river is constantly flowing, the rocks are more eaten away by the chemical action of the water. By careful observation in such places one can trace the average depth and flood levels of the water in the river.

3. *Modifications produced by the action of springs.*—Springs may be defined as discharges of water from within the earth. They, like running water, act in various ways upon the surface and crust of the earth. The small percolating current acts in the same way as the mighty torrent, gradually abstracting material from the rocks through which it makes its course, and leaving cavities which allow the overhanging portions to fall in; in this way they are powerful agents in promoting land-slips and various sinkages and movements of the crust.

Mineral springs are of many kinds; they act chemically both in dissolving and redepositing mineral matter, at the same time acting mechanically like all moving water, as has been explained. Some mineral springs are *saline*, or contain salt; some are *chalybeate*, or iron-bearing; some *siliceous*, or contain silica; some *calcareous*, containing lime; while many give off sulphurous or other gaseous vapours.

Limestone, as has been remarked above, is a rock which is most easily attacked and eroded; it is a rock formed largely of carbonate of lime. Subterranean and also surface water, even when pure, but more readily when containing carbon dioxide, attacks this rock very readily, removing a certain portion of the lime carbonate in solution; in process of time large caves are hollowed out in this manner. But these calcareous waters can only retain the carbonate of lime as long as they retain their carbon dioxide; when, therefore, partial evaporation takes place they drop some of the carbonate as a fine white powder. In this manner a drop of calcareous water

percolating through a hole or crevice and hanging there for a minute will lose a little of its carbon dioxide by evaporation, and will at once precipitate a proportionate amount of its lime carbonate; presently a fresh drop will appear in the same place and the same action will be repeated, until in time the precipitate is lengthened out into what is called a *stalactite*. When the precipitation takes place upon the floor, and the growth of the deposit is upwards, the masses formed are called *stalagmites*.

FIG. 33. — Stalactite (showing successive layers of growth).

All calcareous springs passing through rocks abounding in lime deposit more or less thick masses of lime carbonate. Such deposits are known as *calcareous tufa* or *travertine* (see page 102, Section III.). The precipitation of this carbonate of lime is often hastened by the action of mosses and plants in liberating the carbon dioxide in the water.

Chalybeate springs contain iron sulphate. They may be readily recognised by the brown precipitate (*ochre*) which they leave in their trail and by their inky, medicinal taste. Chalybeate water is largely instrumental in the cementing and consolidating of sands and gravels.

Hot springs or geysers generally contain a large proportion of silica. This silica is deposited in very large sheets and terraces round the geysers in many parts of the world, often forming very beautiful and delicately tinted masses. The substance so deposited is called *siliceous sinter* (see page. 103, Section III.). Both mechanically and chemically, therefore, springs perform a very considerable part in the alteration of the earth's crust. They cause landslips and make huge underground caverns; they bring large quantities of mineral matter in solution to the surface. Some of this is transported to the sea, but a large amount is redeposited on the land as *calcareous tufa*, *siliceous sinter*, or *ochre*.

4. *Modifications produced by lakes.*—A careful observer will note in reference to lakes that they act as filters. A

stream or river enters a large placid lake at one end muddy and turbid, but the river leaving the lake is clear and pellucid. It is therefore certain that the gravel, sand, silt, and débris brought by the contributing streams do not leave the lake, but are deposited upon its floor. In the course of time the lake becomes more and more silted up, until the expanse of water is entirely replaced by a marshy flat with a river meandering through the centre. How this is effected may be conveniently seen by studying fig. 34.

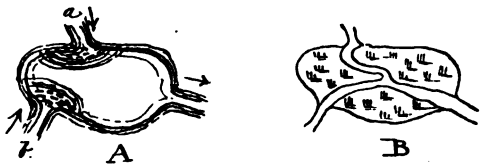


FIG. 34.

A. Lake gradually being filled with the gravels and silts brought in by streams *a* and *b*.
B. The same entirely filled and turned into a marsh.

A turbulent stream entering a lake will deposit its heavier burden first, the finer sand and sediment being carried along to further distance from the inlet, only to be deposited in the almost quiet waters of the centre of the lake. It is a matter of comparative ease, therefore, to trace the original form and the inlets and outlets of ancient lakes. At the entrances of the contributing streams, and for some distance along the course of their currents, the heavier gravel and sand they bore will be found; these will give place to deposits of the finer sand; and, finally, the centre and outlet will be marked by layers of what was once the silt. The deposits formed in lakes are naturally of finer grain than those formed by more violent waters, and may consist largely of fine-grained slates and shales.

Shell-marl (page 104, Section III.) formed of the crumbling shells of freshwater molluscs is often found in lake deposits, and in some parts of the world grains, balls, and flattened pieces of hydrated iron peroxide are gathered from lake floors and used for commercial purposes.

But while treating of freshwater lakes we must not forget that there are also large *salt*-water lakes in existence, and

that they too aid very materially in the changes taking place upon the earth's surface. The Dead Sea, the Great Salt Lake in Utah, and many others in Australia and Africa are examples of salt lakes. Such are entirely surrounded by land; and although it is supposed that they were fresh-water lakes with inlets and an outlet, they have now no outlet at all; water running into such lakes does not escape by means of an outflowing river, but is evaporated back into the atmosphere. So long as there was a constant stream of water entering and leaving the lake, so long the mineral salts held in solution in these waters were, for the most part, retained by them; but when the outrunning ceased and the water commenced to evaporate the mineral salts held in solution began to be precipitated. (See page 12, Section I.) The two chief salts contained in such waters are, commonly, gypsum or lime sulphate ($CaSO_4$) and common salt or sodium chloride ($NaCl$); other salts sometimes present are sodium carbonate ($NaCO_3$), magnesium chloride ($MgCl$), and potassium chloride (KCl).

When 37 per cent. of the water containing these salts in solution is evaporated the gypsum is precipitated, while the common salt is not thrown down until more than 90 per cent. of the water has been evaporated. Such deposits, therefore, are found with the gypsum beneath and the common salt above; and they are not only useful in themselves as valuable commercial products, but because they point to the levels which a lake must have successively and relatively assumed, to the climatic influences which must have been at work in order to bring about their deposition, and perhaps, too, because they give us some idea of the length of time that was occupied in their deposition—data which, compared with that existing, cannot fail to be of scientific interest and practical value to the geologist.

Thus, chemically and mechanically, both salt and fresh water lakes are largely instrumental in modifying the earth's surface.

5. *Modifications produced by the action of the sea.*—No one who has lived by or near the sea, or has observed pictures illustrating coast scenery, can have failed to notice the im-

mense changes which the sea is instrumental in producing upon those portions of the earth's crust brought within the sphere of its influence. In some places the cliffs are undermined by the rude force of the waves, in others portions of the coast have been entirely cut off from the mainland. Here one sees groups of natural arches and caverns, hollowed out of the solid cliffs by the waves; there the eye is arrested by a wide-reaching beach, pounding back a river, or covering the fertile country shore with stretches of barren sand. In whichever direction we look at the land forming the coast we notice evidences of the sea's ceaseless and powerful action upon it.

As the eventual receptacle for the greater portion of all materials washed by rain into the rivers, and carried onward by them, the sea contains, buried under its restless surface, evidences of the great changes which have taken and are taking place upon the surface of our earth. In later days we have been enabled by means of dredging to unravel some of the geological mysteries hitherto hidden upon the ocean floor; to these we will briefly allude further on.

But the more evident action of the sea is to be observed in the demolition of the coast-line bordering its margin. Its action, like that of rivers, is both chemical and mechanical, the latter being the more apparent and destructive.

Walking along a mile or two of coast-line and carefully observing the beach, one may pass first over a stretch of shingle, strewn with rough subangular blocks; looking up and comparing the rocks on the beach with those forming the cliff, one can easily recognise that they have come from above, having been dislodged by some one or other of the great atmospheric modifying causes; now they are within the reach of the action of the sea, which will in a comparatively short space of time wear them down into smooth and rounded pebbles and shingle; such pebbles and shingle we see, in fact, beneath the lately fallen débris, or further along, where no fall of cliffs has lately taken place. But the waves have not done with these pebbles yet. Walking a little further, one passes over a reach of fine white sand; examine it carefully and it will be found that it is composed of exactly the same material as the pebbles, worn much finer, because

it has been for a longer period exposed to the breaker action.

But the cliffs themselves bear evidences of the action of the waves as well as the beach. The marks of successive tides

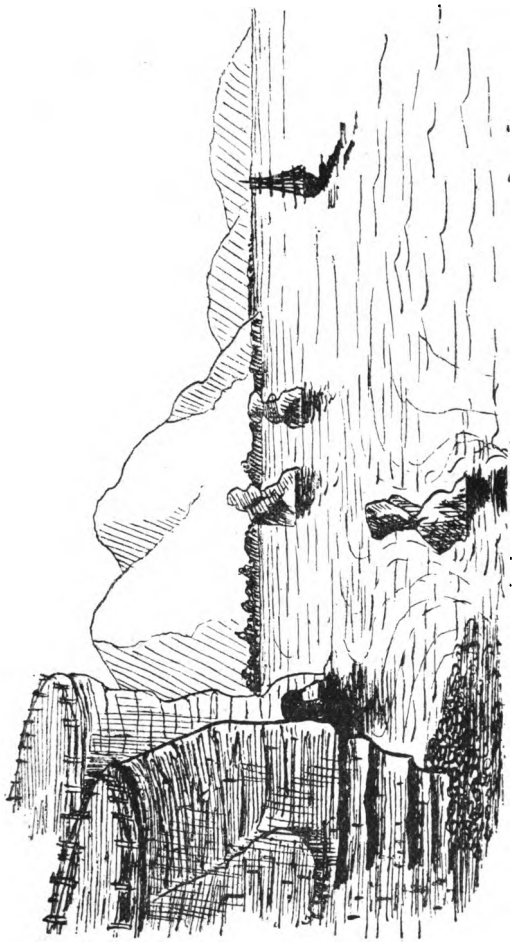


FIG. 35.—Showing detached pieces of former cliffs, wave lines, and a natural arch formed by the action of the sea.

are shown by corrugations of the face, one above the other; out at sea a little, one can see the waves breaking ceaselessly upon a ridge of rocks which mark the line of the coast in bygone days, and which has been so worn down that the little

reef, which once formed a barrier to the progress of the waves, is now only to be seen at low water; between it and the shingle upon which we are walking is a pillar left standing, around which the waves at high water completely flow, and which is slowly but surely succumbing to the ceaseless lapping of the water.

Looking far ahead at the distant cliffs, we can see where the waves, which never there recede from the land, have hollowed out caverns and arches, undermining them until large unsupported masses fall upon the shore, to be in turn pounded and ground into pebbles, shingle, and sand.

Slowly but surely, therefore, the sea is wearing down the surface of the land, until, if the action were sufficiently prolonged, the land would be entirely worn down to sea-level. Such a time, however, is of course enormously far distant. Professor Geikie has estimated that 'if we suppose the average rate of demolition to be ten feet in a century, then it would take not less than 52,800 years to cut away a strip, one mile broad, from the edge of the land.' [1]

The large number of mineral salts held by the sea in solution are also active agents in dissolving rocks, gravels, and sediments. And one cannot fail to have observed the rapidity with which iron rusts when exposed to the moisture and winds rising or blowing from the sea.

The question may now be asked, What becomes of all the substances received by the sea from the rivers or from off the land?

In the first place, at and near the mouths or estuaries of rivers with a sluggish current, one can observe at low water long reaches of mud extending far out towards and under the sea; in process of time these accumulations are raised to such a height that they become permanent alluvial land. Again, in cases where rivers are more rapid, or where they are liable to sudden influx of storm-water, they rush with more or less violence towards the sea, bearing their burden of land-gathered débris; meeting the sea, the force of the current is checked and part of the débris dropped, forming, as is the case in many South African rivers, bars across the mouth or entrance. In

[1] *Geikie's Class-book of Geology*, p. 99.

both these cases the sea may be said to refuse to take the débris offered it by the rivers; but the dredging operations which have taken place in late years show that not only does the sea take large quantities of earth-worn material, but that it arranges it, when once received, with great precision over its floor. Nearest the land are the larger boulders and pebbles; these are succeeded by gravel, this again by sand, and, at distances of several hundred miles from land, fine silt only is found, as the result of the arrangement of the material brought into the sea. Outside of all these deposits are found variously coloured and exceedingly fine-grained muds, composed, for the most part, of microscopical crystals of rock-forming minerals.

The sea, therefore, is active in denuding, wearing down, and washing away such portions of the earth's crust as come within its power; some of the detritus brought down it throws back or accumulates at the mouths of rivers, and the rest is arranged in certain order over its floor.

6. *Modifications produced by the action of ice and snow.*—Not only in its more common form as a liquid does water assist in producing important and well-marked changes upon the crust of the earth, but in its consolidated forms as *ice and snow* its action is obstructive, destructive, and easily discernible.

Where snow, which is formed of ice crystals, symmetrically grouped, falls in great quantity or on great heights where the temperature is low, it covers the ground with a more or less compact carpet. Where the ground is level, the mass remains stationary until it thaws; but where the surface is steep and precipitous, as on the peaks of mountains, the mass frequently slides bodily downwards into the valleys below, forming what are called *avalanches*.

Sometimes avalanches break away suddenly, and, tearing violently downwards, carry with them large quantities of sand, gravel, and boulders, leaving the rock surfaces bare and exposed for further atmospheric disintegration.

Snow, also, when it melts frequently gives rise to violent and destructive floods in streams and rivers.

Glaciers, or compact ice-sheets, are, however, the cause of

more marked changes than even snow. They are the means of transporting large quantities of loose material from higher to lower levels, and they leave undeniable records of the course they have travelled by grooving and otherwise marking the rocks over which the ice-sheet has passed. A glacier, or ice-river, forming in the mountain heights above, gathers on its surface or along its sides large quantities of boulders, sand, and other débris. Some of this débris falls through cracks and crevices in the ice-sheet to the floor over which it is passing, where the grinding action as it proceeds downwards gives rise to a series of striated or grooved lines on the loose fragments, and, under favourable conditions, upon the bed-rocks below. These lines clearly indicate the direction in which the glacier has travelled (fig. 36). The débris which glaciers carry forward upon their surfaces or sides is known as *moraine stuff*. As the glacier gets lower down into warmer regions it gradually melts, leaving the débris in lines and mounds of shingle and boulders, which are known as moraines. Looking down the valley, the left-

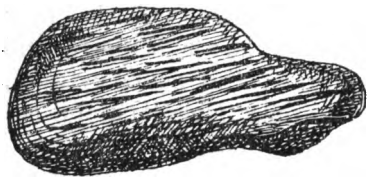


Fig. 36.—Ice-grooved Stone.

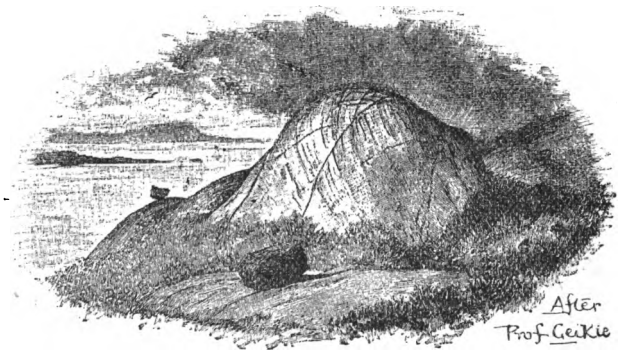


Fig. 37.—Perched Blocks.

hand line of débris is called the *left lateral moraine*, that on the right the *right lateral moraine*; where two glaciers join and the right lateral moraine of the one unites with the left

lateral moraine of the other, they form what is termed the *medial moraine*; while the débris which is pushed in front of the ice-sheet is called the *terminal moraine*.

Glaciers do not always maintain the same level; from season to season they are ever changing their height, sometimes rising and sometimes falling. The falling of glaciers which contain boulders gives rise to *perched blocks*, which are frequently to be seen. Such blocks *must have* been placed *in situ* by some quiet agency, which, gradually subsiding from around them, left them in their present position. It is obvious from their size and delicate poising that water could not have brought and left them in the places they are now to be seen occupying.

Icebergs are masses of ice and snow which have been detached from some ice-bound polar shore. They too very frequently carry enclosed in them large as well as small rocks, which they have gathered in process of formation. Current- or wind-driven into warmer latitudes, they melt and drop their solid burden upon the ocean bed beneath. In latitudes where a severe winter is experienced, both lakes and rivers are often completely frozen over; when the ice breaks up large quantities of it are driven violently ashore, piling up huge masses of detritus, which remain as a monument of the force and the pressure of the shore-driven ice.

FIG. 38.—An Iceberg.
The dotted lines show the approximate bulk of the berg beneath the surface of the water.

It is therefore evident that, whether as ice or snow, frozen water is an active agent in transporting already detached portions of the earth's crust from one spot to another. Further, it leaves records of its presence and action in the grooves and striations upon rocks and rock surfaces, by means of perched blocks, and by the lines of detritus which we call moraines.

7 and 8. *Modifications produced by volcanic and vulcanic action.*—Among the most important of the causes which modify the appearance of the earth's surface must be reckoned

the agency of volcanoes and deep-seated vulcanic action. These agents differ in two essential points from those which we have been considering. Hitherto we have seen that the tendency has been to *wear down or reduce* the earth's surface to one uniform platform by causes acting mainly from without; now we have to study the causes which operate in re-establishing the inequality of the surface by agencies acting from within the planet. There is a great difference, though often an intimate connection, between *volcanic* and *vulcanic* action. The former includes the action of volcanoes and vulcanic vents, ejecting vapours, steam, lava, &c., and is always more or less catastrophic and violent; while vulcanic action, although it includes earthquakes, is for the most part brought about by gradual and often greatly prolonged crust movements.

It is not necessary here to discuss the question as to the composition of the earth's interior; it will be enough for us to note that inasmuch as we find a gradual increase of temperature as we descend into the bowels of the earth, that hot springs, often at boiling heat, are ejected from geysers, and that volcanoes are constantly throwing out steam, red-hot and molten stones, and lava, we can come to no other conclusion but that within the earth are vast quantities of molten minerals.

In all cases where deep wells or shafts have been sunk it has been found that the temperature increases at an average rate of 1° F. for every 64 ft. increase of depth; so that if this rate of increase were maintained we should at a depth of about 175,000 ft. find a temperature sufficient to melt wrought iron, assuming the surface temperature to be 50° F.

The solid crust of the earth therefore can only be supposed to be about $\frac{1}{240}$th of its entire diameter; within this crust are, probably, vast quantities of molten minerals, which do not, however, appreciably heat the overlying crust; it is thus clear that as fast as the crust receives heat from the interior it radiates it off into space, so that the vital heat of the earth must have been getting less throughout all ages.

What is a volcano? Typically, it is a conical-shaped hill which has been built up out of the material which it has itself ejected; within, in the centre, lies the crater, which forms the

funnel to the pipe or vent communicating with the molten mass below. The crater of an extinct volcano, with its heaps of cold ashes, its core of hard and glistening lava, or the yawning chasm of an active volcano with its lakes of molten lava below, and its shroud of hot ashes and scoria around, are evidences of internal activity which all must note.

When a volcano is in active operation the air is rent from time to time with a noise like a large explosion of dynamite; the throat B (fig. 39) is forced asunder, and masses of hot ashes, with flames, steam, and vapours, are belched forth into the air. If great underground pressure is brought to bear the column of lava, E, is forced up, and streams of molten lava pour down the surface, D D, and may stretch for miles over

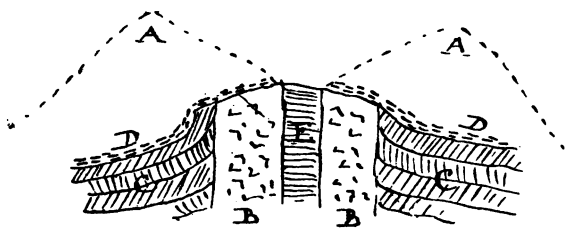


FIG. 39.—Section of a Volcanic Vent.

A. Heaps of ejected material. B. Throat; fragmentary material. C. Sedimentary strata. D. Lava streams. E. Core; lava.

the plains below, after entirely obliterating the physical and vegetable features of the land.

It is obvious, however, that the best chance of observing the results of volcanic action is with extinct volcanoes. When such a one as is shown in fig. 39 ceases to be active, the throat B and core E become solid, and the surrounding streams of lava and heaps of heated scoria gradually cool; subsequent investigation will show us that the lava sheets have cooled from the upper and under surfaces towards the centre, and that the top of a lava sheet which contains steam-cavities is more cellular than the under parts, owing to the facility with which the imprisoned steam could escape. Such cavities, too, being spherical, are often seen elongated in one direction, leading us to form accurate conclusions as to the direction in which the lava current has travelled.

In addition to lava, large quantities of heated stones, ashes, and fine dust are ejected, which form beds of considerable magnitude, and when consolidated are called tuffs. Pumice, which is merely a steam-frothed lava, is a typical volcanic product. Fine volcanic dust is often borne for hundreds, and even thousands, of miles for weeks and months together, as was the case after the great Krakatoa eruption in 1883.

Fig. 40.

But beside the actual cone of the volcano there are generally other vents or fissures in connection with it; it will generally be noticed that volcanoes lie along a well-marked line of fissures. At the time of a volcanic eruption the explosion and concussion are often so great that fresh gaping fissures are opened; in some cases these are filled by minerals deposited by condensation or sublimation (see Section IV., page 150); but in others—and these are the more general—the fissure is filled with lava, which, cooling and consolidating, forms a permanent record of the disturbing influence at work; such lava-filled fissures are known as *dykes*. The lava forced up through the vents does not, however, always stop at the mouth of the crevice; large sheets spread out in various directions, and often cover the country for miles around. By observing the vegetable and animal remains preserved within these sheets, and by noting the different formations in which they occur, one can approximately judge of the condition of life at the time of their eruption, and locate them in their proper geological epoch.

Again, we have had oft-recurring evidences during the existing human epoch of subterranean energy—the evidences of earthquakes and tremors. The seismometer tells us that earth tremors are much more frequent than they are generally thought to be. They are productive of huge rents and gaping fissures in the earth's crust, of permanent dislocation and misplacement of the various strata forming the outer crust of the globe, of landslips, and of variations in the level of the sea whereby many destructive incursions of the ocean have been

caused. An earthquake, however, is not always catastrophic; lesser movements of the earth, lasting over greatly extended periods, are always in operation; parts of the earth are known to be gradually subsiding, parts are known to be rising.

It is believed that the great mountain chains, as well as the lesser hills, the crumpling and folding of the earth's surface into its present arrangement of hill and dale, mountain and valley, have all been, to a large extent, brought about and formed by vulcanic action of varying degrees of intensity. The fissured beds and sudden breaks in the continuity of strata point, it is true, to violent movements; but the unbroken regularity of a series of beds, which, although tilted from their original horizontal position, still remain intact over a long reach of country, point most conclusively to slow, persistent, and quiet movements from below.

In whatever direction we look we see unquestionable evidences of volcanic and vulcanic action. Shales and slates, which represent the mud floor of some ancient sea or lake, are now tilted nearly or quite upright; sandstones and conglomerates, originally deposited in horizontal layers under water, are now tumbled and tossed in well-nigh endless confusion; limestones, with their interbedded fossils, are crumpled so that the organic remains are hardly discernible or determinable; while here and there huge dykes of consolidated lava cut through all the strata with irresistible energy and precision; all these features tell the story of the great pent-up forces within the outer solid portion of our planet.

9. *Modifications produced through the agency of plants and animals.*—To the prospector and miner the changes wrought by plants and animals are perhaps of secondary importance; yet a knowledge of them will be useful to both, chiefly as a means of correlating or comparing various strata, which may often be widely apart. Their entombed remains are the basis upon which geological history has been largely built up.

The action of plants and animals is of two kinds, *destructive* and *accumulative*. Many animals, for example, burrow in the earth, throwing up the cores and leaving holes down which water finds its way, enlarging the tunnel until it has made a permanent subterranean passage; others again, such as the

coral insect, build up large accumulations out of their remains; peat and coal are accumulations of vegetable matter; while, on the other hand, all decaying plants and dead animals furnish the ground with various acids which help to corrode and destroy the rocks of the earth.

Under the section on Petrology the rocks formed of animal and plant accumulations will be found fully described.

The fossils contained in rocks are many of them of entirely extinct species both of plant and animal life, few species found in the most ancient rocks having existed through the various geological ages up to the present. But these fossils can all be referred to various types of life, and they show in all cases a uniformity of evolution from a lower species of life in the older strata to a higher species in the younger.

Certain forms of life are found to exist all over the world in certain strata, and to be entirely absent in those either above or below, and upon the occurrence of these fossils geologists have been led to fix the age of various stratified and unstratified deposits.

The science of the study of fossils is called *Palæontology*, and necessitates a knowledge of biology, zoology, and botany. In a work such as this it is impossible to enter into this most interesting subject; but, in order to aid the student in correctly classifying in its proper geological order any fossilised rocks he may find, typical fossils are described and depicted in Chapter IV. of this section; and to still further aid him, a table is added at the end of Section VI. giving useful particulars regarding the classification of the vegetable and animal kingdoms.

CHAPTER II

The Structure of the Earth's Crust

Having in the last chapter considered the various causes which have been and are instrumental in promoting modifications in the earth's crust, we must now turn our attention to a consideration of the general arrangement of these modified strata, beds, and deposits. In order to understand this with any degree of success, it will be necessary to consider, in the first place, the conditions of their original deposition, and afterwards to study the evidences of subsequent movement and rearrangement into the various positions which they now occupy, examining also the changes which have been induced in them by these movements.

A simple and comprehensive division of rock formations may be made upon the same basis as that given in the section on Petrology, viz. *stratified rocks* (aqueous, sedimentary), or those which, appearing in certain well-defined layers or strata, owe their origin to their deposition by or under water, or to one or other of the various external modifying agencies; and *unstratified rocks* (igneous, basic), or those which, owing their origin to either volcanic or vulcanic action, do not occur in strata, but are amorphous or crystalline. Examining this classification more closely, it will be seen that the former group owe their origin to causes acting from *without*, while the latter have been placed in their present position entirely by causes acting from *within* the earth; some rocks, such as crinoidal limestone, do not appear stratified, but inasmuch as they have been formed by organic life living *upon* the earth and not *within* it, they are more properly classed with the externally formed than with the internally formed rocks. But in addition to these two great divisions geologists have formed

another class of rocks which are termed *metamorphic* (or those with an altered form). We shall, however, not introduce this class into this work, for it is clear that metamorphism must have taken place upon some already existing formation, and that it is merely the result of *a force* which has produced alterations in some already deposited externally or internally formed rock. So-called 'metamorphic' rocks, therefore, will be excluded from our classification, any species usually placed in this class being referred to *metamorphic stratified* or *metamorphic unstratified* rocks.

Stratified Rocks (Aqueous, Sedimentary).

Original deposition.—One of the commonest features in a rocky landscape is the appearance of the rocks in certain well-defined layers; such rocks as sandstones, conglomerates, and shales, having been originally deposited under or by water in the form of sand, gravel, or mud, must have, of necessity, been accumulated in successive layers, each one of these layers or *strata* representing, probably, a continued period of deposition, the lines dividing one stratum from another representing a cessation of deposition or an alteration in force or direction of the depositing current.

Where a series of these occur one upon the top of another, it is certain that the older deposits are at the bottom and the younger on top. By a careful observation of the arrangement and nature of these beds, one can arrive at a conclusion concerning the state of the water and the varying conditions generally under which they were deposited. In fig. 41 *a* represents a bed of shale containing, perhaps, a few fresh-water fossils; such a deposit shows that the water under which it was deposited was muddy, and that the current must have been gentle, or else the fine silt would have been swirled away into quieter waters; *b*, a sandstone bed, points to a more rapid current in which only the heavier particles were deposited; *c*, a layer of gypsum, shows that after the deposition of sand the water, which must have contained lime-sulphate in solution, was evaporated to the extent of at least 37 per cent. (page 115); *d*, another bed of sandstone, points to the influx of more turbid water, and the consequent cessation

of the depositing of gypsum; *e* is a bed of gravel, which clearly points to the fact that the water must have been augmented from some source, and had gathered sufficient force to carry small pebbles along in the current; once more the supply of water ceased, evaporation set in, and another bed of gypsum (*f*) was precipitated, while *g* and *h*, both sandstone strata, point to renewed influx of water; these are succeeded, perhaps, by *i*, a bed of fireclay which formed the soil upon which *j*, a consolidated and mineralised vegetation (coal) once flourished. Such a section is, of course, typical, but it is by the inferences which can be drawn from existing strata in a similar manner that geologists read the history of these deposits.

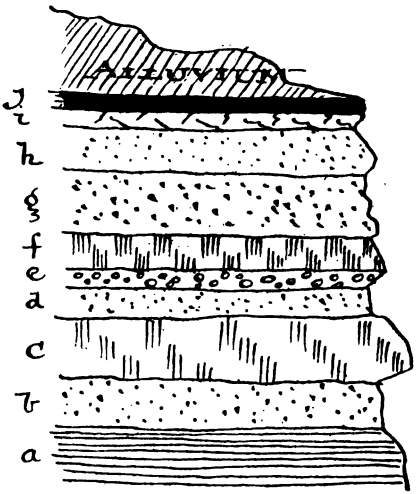


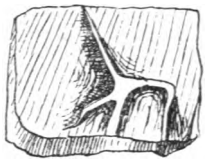
FIG. 41.

The divisions in fig. 41, described above, are known as *strata*; *a* is a stratum of shale, *b* a stratum of sandstone, *c* a stratum of gypsum, and so on. If *a* be carefully examined it will be seen that it can be split up into various thin leaves, which are called *laminæ*; such laminæ are in reality small strata, and are generally found in only the finer-grained sedimentary rocks. The stratum *b* will not probably exhibit any laminæ, nor will *c*, although in this latter case the want of lamination is due to the fact that gypsum ($CaSO_4$) *crystallises* out of solution, and not on account of any variation in the direction and force of the depositing current, which was, in fact, not flowing when the gypsum was precipitated.

Strata are not *always* deposited horizontally; on page 86 it has been pointed out that the strata may be quite unparallel for a while, such unconformability being due to the unequal surface of the bed rock; or again, a sudden change

in the force of the current, which would be produced by an alteration in the inclination of the bed, may cause larger quantities of sediment to be deposited in one place than in another, thus bringing about an unequal depositing of strata. When such stratification or bedding is observed it is called *current-bedding*.

Other peculiarities of stratified sedimentary rocks are to be noticed, and the proofs that they give of the presence of land, water, wind, sun, and even life at the time of their deposition are interesting and well worthy of recognition. Casts of sun-cracked surfaces show that a muddy soil had been dried by a sun and had been cracked in a similar manner to that which we see taking place nowadays; rain-prints, by the impressions they have left, show that heavy rains fell upon the soft, yielding mud or sand; side by side with or among these rain-prints may be seen the footmarks of some shore-living animal or bird, pointing conclusively to the presence of life in these times. A common occurrence in some sandstone is that of a ripple-marked surface; such surfaces show that the sand so marked must have been upon some tidal shore, over which the waves were quietly lapping, even as we see them to-day upon flat reaches of sandy sea-beach; in connection with all of these marked surfaces it is clear that the causes operating to cover up their evidences with a fresh layer of silt or sand must have been both gradual and gentle, or the marks would have been obliterated.



Plan of cast of a sun-cracked surface.

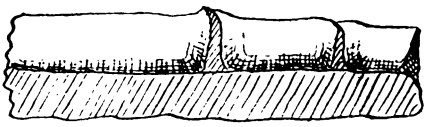


Fig. 42.—Section through a stone bearing a cast of a sun-cracked surface.

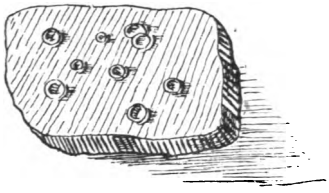


Fig. 43.—Rain-prints in Shale.

How long each stratum of sandstone, shale, or limestone was in process of formation we have no definite gauge wherewith to measure, but some guide has been given us in the remains of upright trees, which were evidently covered up by degrees while still growing, for their roots may be seen attached to the trunk and striking out into the formation around; we know that trees cannot live for long when once partly covered, so that, by comparison with existing similarities, we can arrive at a rough calculation as to the time occupied in forming a certain depth of strata; the guess, however, can be but a vague one, as the conditions under which similar deposits are now forming are very varied and the results far from uniform; but one thing *is* certain: deposits of fine-grained slates and shales must have been much more gradually laid down than were the coarser sandstones. Inasmuch, too, as every bed of sandstone, shale, and conglomerate represents a similar amount of material worn off the surface of the land, it is clear that *enormously* prolonged ages must have passed before the present series of stratified rocks could have been completed.

Evidences of movement after deposition and consequent altered appearances and structures.—During these periods of quiet deposition there were, undoubtedly, periods of planetary excitement, when the pent-up forces within the earth broke through or tilted the superimposed strata; these outbursts were again succeeded by renewed quietude, when the wearing down, transporting, and rearrangement of strata proceeded with more or less regularity as before. The alternation of the work of these two different agents gave rise to what is known as *unconformable strata*; presuming that the strata A A in fig. 44 are recognisable by means of fossil remains imbedded in them, and that they can by this means be referred to the Carboniferous system, and that those forming the strata B B can, in similar manner, be referred to the Permian system, it is clear that the vulcanic force which tilted A A

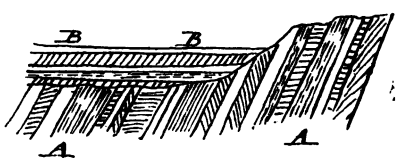


FIG. 44.—Unconformable Strata.

must have acted at a time subsequent to the Carboniferous age and previous to the Permian, and the strata A A are not conformable to the strata B B; in a manner similar to this, the geological age of mountain chains can often be determined and mountain ranges in one part of the world be recognised as coeval with those in another.

But, as has been pointed out on page 122, parts of the earth's crust have been and are sinking as well as rising, evidences of such sinking being discernible in many mountain ranges; hills of great height are found in which the strata, from bottom to top, are crowded with evidences of their deposit in proximity to water or upon marshy shores; these evidences, such as rain or foot prints, ripple-marks, or sun-cracks, could not have been brought about except under the conditions previously explained, and they therefore show that each one of the ascending strata was *at one time* on a level with the sea. We can only account for their presence in the topmost strata on the supposition that as each stratum was deposited the land gradually sank, and a fresh one, bearing new evidences, was laid down upon it; this too sank, until the whole series was completed and the sinkage stopped; at a subsequent date, and after the consolidation of the series, the whole was again upheaved, far above its original height, by vulcanic action.

We have already seen that one series of stratified rocks may be unconformable to another, and that such unconformability has been induced by vulcanic agency; the same action

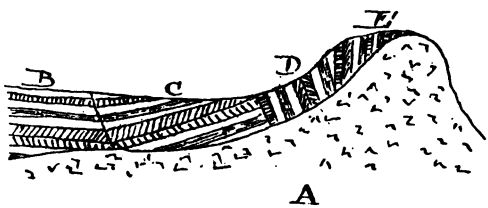


FIG. 45.

has been instrumental in altering the original horizontal bedding in many different ways. For example, in fig. 45 we see that the vulcanic or igneous rock A has been instrumental

in altering the original horizontal strata B with varying degrees of intensity. At B the strata is *horizontal*, at C it is *inclined*, at D it is *on edge*, and at E it is *thrown up*. Sometimes the strata has been sufficiently pliable to withstand the torsion without a break, merely bending to the subterranean force; such strata are called *contorted*. The folds A A, fig. 46,

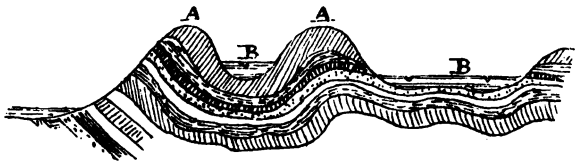


FIG. 46.—Contorted Strata.

are called anticlinal (*klino*, I bend; *anti*, in opposite directions); those at B B are known as synclinal (*klino*, I bend; *syn*, together). Where the strata are all dipping away, at different angles perhaps, but from one common centre of disturbance, they are known as *monoclinal* strata (*klino*, I

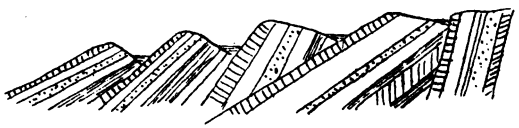


FIG. 47.—Monoclinal Strata.

bend; *monos*, alone); where they terminate in a bold headland, either on land or by the sea-shore, such headlands are known as *escarpments* (*escarpé*, steep); while portions of them lying away from the main body are known as *outliers*.

FIG. 48.—Escarpments and Outliers.

Faults.—The excessive strain to which rocks have been at times subjected has been the cause of the strata snapping asunder; in the majority of cases in which these ruptures

have occurred, the strata so broken have not met together again in their lines of original horizontality, but one side or the other, or both, has risen or sunk; such ruptures are known as *faults*. A fault is seldom vertical; in the great

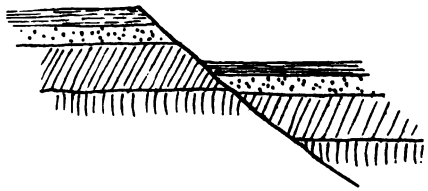


FIG. 49.—A Fault.

majority of cases it is inclined at a steep angle, and the *hade* of the fault or the angle of inclination of the break is away from the side that has risen or towards that which has sunk. Such is known as a *normal fault*, and they are by far the

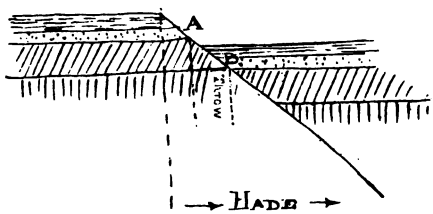


FIG. 50.—A Normal Fault.

most common. The *throw of a fault* is the *vertical* distance between the sundered portions of the same stratum, as from A to B in fig. 50. Sometimes there is a small amount of crushed matter between the two sides of a fault, and this is known as *fault-stuff*.

Dip, outcrop, strike.—The *dip* of a rock is the angle of its inclination from the horizon. The *outcrop* is the upturned edge of a stratum appearing above ground. The *strike* of a stratum or of a series of strata is the direction in which it runs, and is usually referred to the *magnetic north*; the strike is of course at right angles to the dip.

Before considering the altered appearances and structures of stratified deposits which have been induced in them by these various movements, it will be necessary to note that some change must have taken place by which they were

altered from incoherent deposits of gravel, sand, or silt into solid, coherent rock-masses. This process, which is called *consolidation*, has been effected by the action of natural cements, such as silica, lime carbonate, and iron peroxide; these cements have been introduced either by percolating water holding them in solution, or else by precipitation from the

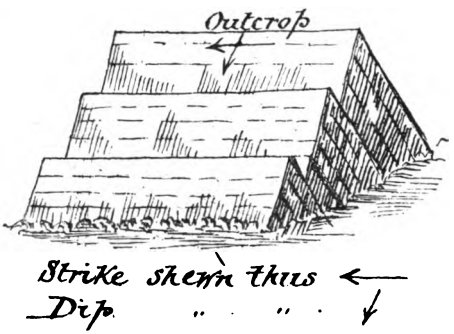


FIG. 51.

waters in which the materials were themselves laid down. The great pressure to which rocks have in some cases been subjected has also been a means of consolidating them, as in the case of coal, which, having no inherent cementing material, has become solid from the pressure of the beds subsequently piled above the layers of vegetation of which it is composed.

Joints.—Many rocks, such as sandstone, limestone, or chalk, are divided into well-defined blocks, the division planes between them being called *joints*; one set of these joints is

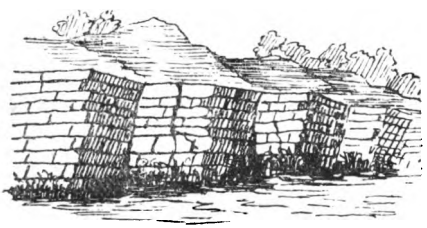


FIG. 52.—Jointed Strata.

parallel to the dip, while a distinct series is at right angles to it (fig. 52). These joints have been formed partly by the compression brought about by the earth movements, partly as

the result of the torsion or twisting produced by such movements, and also, probably, to some extent by the contraction of the rocks as they became drier upon consolidation. Joints, therefore, are the direct result of the altered position of rocks brought about after deposition.

Cleavage is the name given to an important and very general structure in stratified rocks which have been subjected to movement from their original planes. Examining a piece of slate, it will be seen that it has a tendency to split into thin leaves. This cleavage or splitting into leaves must not be confounded with *lamination* (see page 99); the laminæ of a fine-grained rock are the result of a cessation or alteration in the force or direction of the depositing current. Cleavage, on the other hand, is the direct result of *intense pressure*, whereby the particles of which the rock is formed have arranged themselves in such a position that they offered the least resistance to the pressure.

Metamorphism.—It is hardly to be supposed that the texture of rocks will have, under these various movements and enormous pressures, remained the same; rocks have in point of fact undergone very great changes in texture, and these changes are known as metamorphism. Metamorphism is of two kinds—*contact* or *heat metamorphism* and *regional metamorphism*, or that resulting from great pressure, torsion, or both.

It is impossible to conceive a sandstone stratum broken, twisted, and thrown far above its original level by vulcanic agency without acknowledging that such great movement must have been accompanied by considerable *frictional* heat. We know, too, by investigations made with the microscope upon the crystals of igneous rocks that the rocks themselves were in a state of fusion. Some portion of these two different kinds of heat must have been induced in the adjacent strata, which show the result of it in different ways. A granular, friable sandstone has been turned into a hard, glistening, crystalline quartzite; limestones and chalks, into bright crystalline marbles; siliceous shales, into jaspers, bloodstones, or hornstones; and soft mud-shales, into hard crystalline slates. Such are some of the results of contact metamorphism.

Regional metamorphism, besides being responsible for the characteristic known as cleavage, has, through the agency of intense pressure, accompanied of necessity by a certain engendered frictional heat, in some cases entirely obliterated the original distinctive features of a rock. In Petrology, Plate 1, page 84, a gneiss is depicted as seen under the polariscope; this gneiss is in reality a granyte which has been subjected to the action of regional metamorphism; the result being that although the mineral constituents are identically the same as in a crystalline granyte, they now appear in certain well-defined layers, instead of being distributed indiscriminately throughout the mass. The example here given is not a stratified rock, having been chosen on account of its very typical character, but all strata which have been much crumpled and tilted show this *schistose structure*, as it is termed.

We see, therefore, that stratified rocks have undergone vast alterations in their arrangement, appearances, and textures since they were first laid down. Originally formed by the levelling agencies at work upon the surface of our globe, they have, through the action of forces within, been subsequently upheaved into that diversity of surface which is not only pleasant to the eye but necessary for the welfare of animal and vegetable life.

UNSTRATIFIED ROCKS (IGNEOUS, BASIC).

The chief varieties of volcanic, vulcanic, or igneous rocks, their occurrences, physical characteristics, and component minerals, have been described under Section III. (Petrology), but it is necessary still to deal with certain geological features which could not be described with consistency in the previous section.

In the first place, it is necessary to remember that these igneous rocks have been the agents which have in all cases upheaved and fissured the superincumbent stratified rocks. Of the vast pent-up forces within the solid crust which have been the primary factors in these great and irresistible movements we have no certain knowledge, but they are generally

supposed to be due to the gradual contraction of the earth, which, as we have seen (page 126), has from all ages been losing part of its vital heat, and is therefore getting constantly cooler. We may also attribute some of the movements to vast subterranean explosions of gases, or to the re-establishment of equilibrium necessitated by the wearing down in one part and deposition in another of various portions of the earth's surface.

The prospector should note that inasmuch as these rocks have been the cause of the fissuring of the earth's surface, it is in connection with them that he has the best chance of finding mineral veins.

Dykes.—One of the results of the upheaval of these igneous rocks is the formation of dykes. Dykes are closely related to faults (page 134), being fissures or crevices which have been

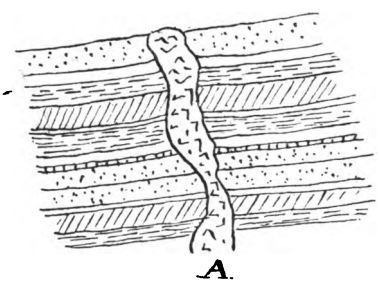


FIG. 53.

A. A Dyke.

opened during a period of vulcanic activity into which rocks in a pasty or molten condition have been forced. On cooling these intrusive veins have crystallised and consolidated in the fissure, forming a vein of rock often quite dissimilar from that through which they have passed. Dykes vary in width from less than an inch up to many feet. They are usually nearly vertical, and often radiate from one common centre of vulcanic activity.

Occasionally the matter filling a dyke has been forced up with such violence that it has overflowed the surface and covered the surrounding country. This is a common feature of basalt, which must have been poured forth in immense

quantities from some dykes. Such beds as are shown in fig. 54 as having overflowed are called *overlying beds*.

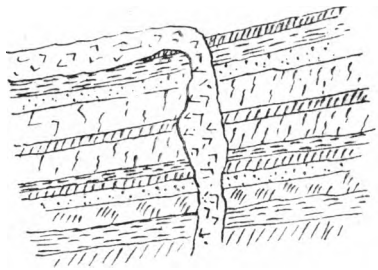


FIG. 54.—Dyke, overlying.

Again, a dyke may be the means of causing an interstratified sheet of vulcanic rock among a series of stratified aqueous ones. This is shown in fig. 55, where the vulcanic rock B,

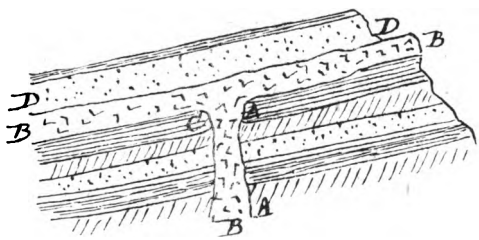


FIG. 55.—Interstratified Sheet.

after following the fissure in the stratified rocks A A as far as C, has turned and passed along the bedding planes D D.

Bosses.—One of the commonest of the igneous rocks is granyte. It appears either in dykes or large widespread

FIG. 56.—A Granyte Boss.

masses (see page 88, Section III.), and it is the chief cause of the formation of what are known as *bosses*. These are in reality fissure veins, or dykes of large size, which have been forced up

with great power. Not infrequently they are found split asunder near the surface, enclosing between their extreme edges portions of the strata which they have fissured. Being

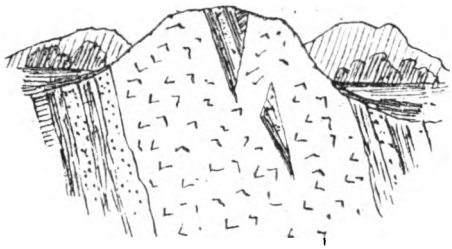


Fig. 57.—Section through same.

harder than the surrounding strata, they have not weathered to the same extent, and so commonly appear as isolated knolls.

Necks are the filled-up and consolidated pipes of once active volcanoes. Standing up within the centre of the old crater, a pillar of hard consolidated lava forms the core of what was once the vent or chimney of the volcano; all around are evidences in the tuff, pumice, puzzolana, and lava of the spent activity, while little imagination is needed to

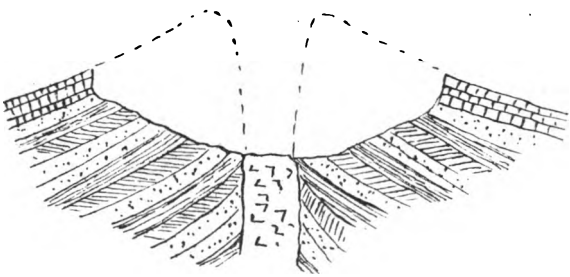


Fig. 58.—A Neck.

restore the once conical form of the hill itself, but which, being more or less incompact, has long since succumbed to the various external denuding agencies.

The chief points for the student to bear in mind in connection with these unstratified igneous rocks are, that they have been the means of fissuring and disrupting the solid crust of the earth, and that by their agency man has, to a very large extent, been brought face to face with the mineral treasures of Nature.

CHAPTER III

Mineral Veins and Deposits

In the last chapter it was pointed out that one of the results of vulcanic and volcanic action, and the consequent disruption and fissuring of the earth's crust, has been the formation of mineral veins or lodes. In as concise and simple a manner as possible, we shall now endeavour to describe the various kinds of mineral veins or lodes, beds, and deposits.

The following classification covers the various kinds of mineral deposits:—

Lodes:
- Fissure Veins.
- Fault Fissures, or Fault Veins.
- Gash Veins.

Interstratified Mineral Deposits.
Contact Deposits.
Flats.
Pockets and Chimneys.
Surface Detrital Deposits.
Surface Chemical Deposits.

Fissure Veins.—These are *true lodes*. The fissures which their minerals and gangue occupy appear to be the result of contraction of the strata during consolidation or while cooling down from a heated condition; they may also be due to ruptures caused by the settling of the strata on either side of the fissure in opposite directions.

No rule can be given for the strike of fissure veins, as they vary considerably in different countries, and even in different mineral districts in the same country; but it is to be noticed that there are upon most mineral fields two sets of lodes, one running at right angles to the other; one set

of these, however, are often *gash veins*. Like dykes, they dip at various angles, the angle of dip frequently changing, more especially where the lode passes from one kind of strata into another; as a rule, the harder the strata the more vertical the lode.

The two sides of a lode are called the *walls*, the upper being the *hanging wall*, and the lower the *foot wall*. When a

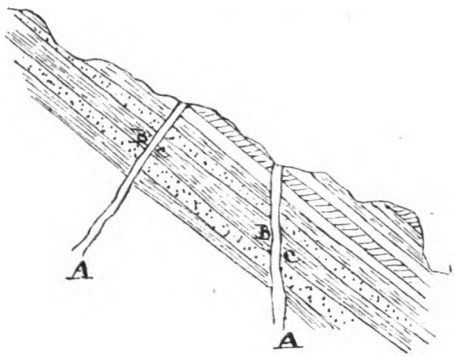


FIG. 59.

A. Lodes. B. Hanging Wall. C. Foot Wall.

lode is vertical the wall next to the *upper* inclination of the strata is called the hanging wall, that on the lower being the foot wall (see fig. 59).

FAULT VEINS.—Instead of occupying a position in continuous strata as a true fissure vein does, a fault vein occurs between the two sides of a fissure which has resulted from a fault. As pointed out when describing faults (page 134), the *hade* of a fault is in the majority of cases away from the raised portion of the strata and in the direction of the sunken portion; the dip of a fault vein will therefore be generally found to be away from the raised, and in the direction of the sunken, portion of the strata through which it passes. No definite rule can be given for the strike of fault veins, but

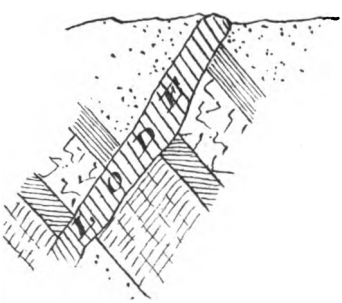


FIG. 60.—A Fault Vein.

they often radiate from the centre of the disturbing influence which has affected the beds through which they pass.

They are more recent than fissure veins, as they are frequently found cutting right through the latter when they cross their path.

Gash Veins.—Gash veins are also fissures, but instead of being continuous in depth like true fissures, they thin or 'peter' out at various inconsiderable depths. Gash veins are a frequent source of disappointment to miners and shareholders, but can generally be distinguished from true fissure veins by their want of clay-lined walls. Fig. 61 is a section of a gash vein on the Sheba Hill, De Kaap. Upon many such as this companies with large capital were launched in 1886 and 1887. Gash veins are surface cracks filled with mineral matter from surface or side infiltration.

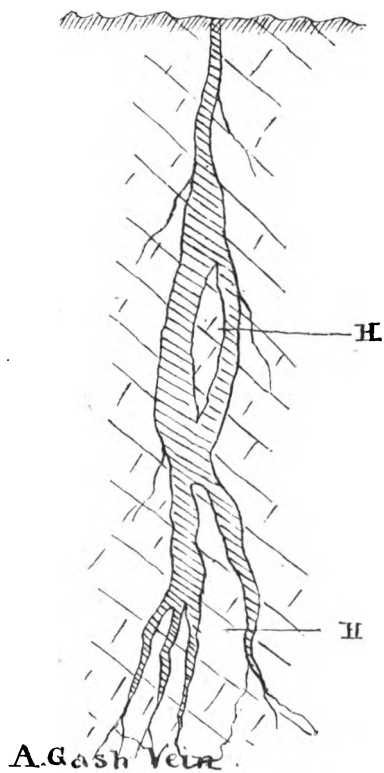


Fig. 61.

A common occurrence in gash veins is what is called a 'horse' (H, fig. 61). Horses are the result of an unclean fissure or fracture, by which some portion of the strata has become isolated from the mass and has been surrounded by the gangue of the lode; or the mineral matter may have forced an auxiliary passage for itself for some distance beside the main fissure, and thus separated a portion of the strata from the general mass.

Interstratified Mineral Deposits.—Minerals frequently occur in mineralised stratified beds. Such deposits are easily

recognised, the minerals being for the most part confined to one stratum, having on either side of it strata which are comparatively barren. The gold-bearing conglomerates of Witwatersrandt, the layers of clay-ironstone in the Coal-measures, and the Keuperschiefer or Copper-shales in the new red sandstone, are examples of interstratified mineral deposits.

Contact Deposits.—These are deposits of minerals and gangue lying between two totally different formations, such as clay slate and porphyry; they form, in fact, a wall along the line of contact of two distinct rock formations (fig. 62).

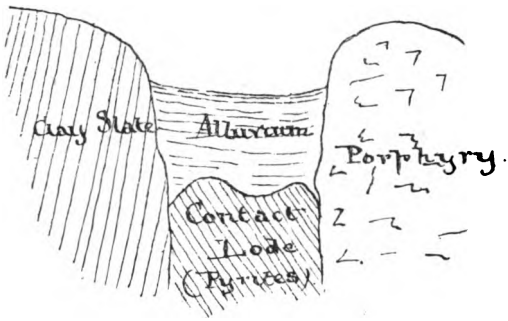


Fig. 62.—Section of a Contact Lode, Huelva, Spain.

The enormous deposits of copper-bearing pyrites at the world-famed mine at Rio Tinto in Spain are an example of contact deposits.

Flats.—Flats are caused by fissures which have not maintained a direct course to the surface, but have for a part

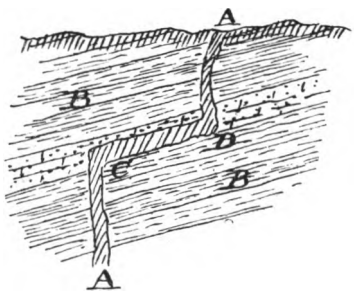


Fig. 63.—A Flat.

of their course followed the line of least resistance. In fig. 63 it will be seen that the fissure A, after rupturing the

hard strata B B as far as C, followed the softer strata to D, when it once more pursued its upward course to the surface. The flat is that portion of the fissure or vein from C to D.

POCKETS AND CHIMNEYS.—Pockets and chimneys of ores are very common in limestone and other calcareous rocks; they are irregular deposits generally, having no resemblance to any other mineral occurrences.

As *pockets*, they appear to occupy cavities in rocks which have been dissolved out by waters containing carbon dioxide, the mineral taking the place of the dissolved rock; as *chimneys*, they fill the pipes or vents of some extinct mineralised spring or fountain, or occupy the vent of some silent volcano. The silver-bearing tetrahedrite mine, New Guston, is an example of a chimney deposit, and so too, probably, are the diamond mines in South Africa.

SURFACE DETRITAL DEPOSITS.—Gold, tin, platinum, and many kinds of gems and precious stones are found in the superficial deposits of the earth. These mineralised deposits have resulted from the various weathering and denuding processes, already explained, upon the matrices which originally contained the minerals, and which are generally in their immediate neighbourhood.

SURFACE CHEMICAL DEPOSITS.—Gold, ores of iron and copper, gypsum, salt, and many other minerals are found in crystallised grains and masses in the superficial deposits of the earth. They are the result of chemical precipitation from water holding them in solution, aided by electricity and organic acids. In many cases they are productive of most useful minerals.

Faults.—It frequently happens that either one of the first four kinds of mineral deposits is faulted horizontally out of its true strike; such faulting is due to vulcanic force which has acted since the fissuring and formation of the vein. In cases where these faults occur the lost lode can generally be recovered by turning along the *obtuse* angle of the fault, which is in reality moving along in the same direction as the disturbing wave had done. In a similar manner, the dip of a lode may be disturbed by a *vertical* fault, and recovery may be accomplished in the same way as in the case of the horizontal

displacement. In cases where the angle of displacement is at right angles to the dip of the lode, careful prospecting and examination of the strata should be made before expensive drifting be undertaken, always bearing in mind that normal faults (see page 134) are the more common.

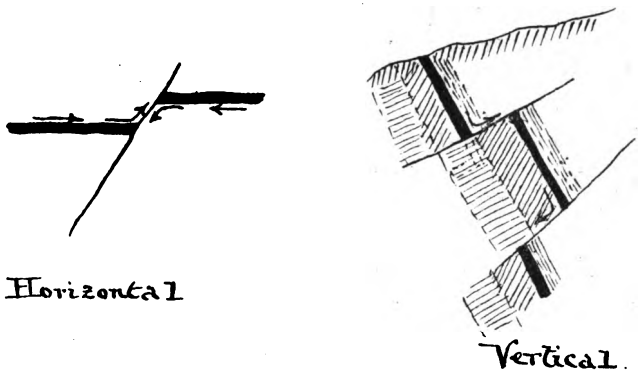


FIG. 64.—Lode Displacements.

The structure of mineral veins (lodes).—Although there are cases in which one mineral alone completely fills a fissure, the matter with which mineral veins are filled is generally of two kinds: the *gangue*, or *non-metallic* portion, which is usually of no commercial value; and the *ore*, or *metallic* portion, which may be of greater or less value.

It happens sometimes that metals, unaccompanied by any non-metallic substance, form the gangue, such as copper-bearing pyrites or silver-bearing lead; but the *chief* gangues of veins are quartz, calc-spar (calcite), fluorspar (fluorite), and barytes.

According to the characteristics of their gangues mineral veins or lodes are described. For example:—

A gossany lode is one in which the quartz gangue is friable and cellular; it is usually coloured yellow, brown, or red, according to the degree of decomposition which the iron it contains has undergone.

Quartz lodes are fissures filled with quartz of various degrees of purity and compactness; the quartz is sometimes white and sugary, sometimes blue and laminated, and sometimes grey and vitreous.

Sparry lodes are fissures filled with fluorspar, barytes, or lime carbonate (calc-spar).

Peachy lodes are fissures filled with gangue in which green, pearly chlorite occurs.

Flucan is the name given to an auxiliary fissure filled with stiff clay. Flucan is generally absent in gash veins. When the flucan is mixed with sand and pebble it is known as *pryan*.

Grouan is the term applied to the material filling a fissure which, passing through granyte, has become filled with partly decomposed portions of this rock.

The metallic portions or *ores* of mineral veins are sometimes native, such as gold, mercury, or copper, but more generally they are metallic salts, such as iron disulphide (pyrites), silver chloride (kerargyrite), copper carbonate (azurite), or copper silicate (chrysocolla).

A careful examination of mineral veins will show that the deposition of the minerals proceeded from the walls towards the centre of the veins, and that the different minerals are, more or less, equally deposited in parallel layers on either side of the centre. In fig. 65, for example, quartz is seen on either wall; the apices or terminations of the crystals being towards the centre, it is clear that they were *first* deposited upon the walls (1–1); after the deposition of the quartz came blende (2–2), which, having ranged itself beside the quartz, was in turn succeeded by fluorspar (3–3); galena or lead sulphide followed (4–4), then fluorspar (5–5), another vein of blende filling the now greatly reduced fissure and completing the lode.

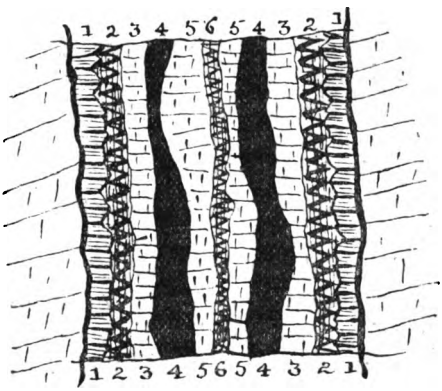


FIG. 65.—Section of a Lode.

Mineral veins do not always maintain an average width; one which appears, at fifty feet depth, to be a solid, compact

mass many feet wide and of great value, may suddenly 'thin' or 'pinch' until it is but a mere stringer a few inches only in width; at a further depth it is just as likely (*if it be not a gash vein*) to expand again, until the miner has the satisfaction of seeing his lode once more of a payable size. Such inequalities in the width of mineral veins are chiefly due to the cohesion and compressibility of the strata through which they pass.

When a vein alters in width the various bands of which it is composed frequently decrease or increase in sympathy; many cases also occur in which one band will suddenly swell out and occupy nearly the whole of the fissure, to the exclusion of its fellow-minerals.

The charging of mineral deposits with minerals.—Having described briefly the different kinds and structures of mineral veins and deposits, we will now consider the question as to the manner in which they may have become impregnated with their various minerals. This question has been for many years the cause of much discussion among, and the propounding of many theories by, mineralogists and geologists; but it has been found, by the light of later experience, that the solution of the problem is not to be found in any one cause, but that different agents have operated upon the deposits in different ways in various cases.

The *nebular hypothesis* supposes that our planet, in conjunction with the whole solar system, originated in the separation and condensation of a small part of an enormous nebula, that is to say, a mass of cloudy vapours, gases, and burning material, like the faint luminous star-clouds which can be seen on any dark night. When any portion of these vapours and burning materials was thrown off it began to condense and cool, and the whole separated mass to arrange and consolidate itself as a globe.

As the cooling proceeded the vapours and gases would condense, precipitating their contained minerals, while the molten metals in a semi-fluid or viscous state would gravitate and settle in whatever hollows, fissures, or cavities were available. Where the cooling was most rapid, that is, on and near the surface of the earth, the metals would undoubtedly solidify

quickly and be there retained; but within the gradually cooling crust, the process of solidification would be much slower; indeed, we have evidence (as we have seen) that it is not yet completed, and that minerals in a fluid state are contained within the globe at the present time.

It cannot be supposed that the elements which form our portion of the great original nebula were evenly distributed over the cooling mass, or that the mass itself cooled equally all over; on the contrary, it is reasonable to suppose that not only would such a large mass, in the immediate neighbourhood of other heated and perhaps larger masses, cool most unequally, but that the heavier metals would, while the whole was still in a red-hot or plastic state, be assisted in their arrangement partly by the temperature of masses adjoining them, and partly by the rotating movement which the earth had begun to make round the parent nebula, of which the sun is supposed to be the remaining uncondensed centre. In such a manner as this we can account for the presence, and to some extent for the unequal presence, of minerals many of which are known to exist in the sun, upon and within the earth.

Let us now endeavour to understand how these minerals came to be deposited in the various beds, veins, pockets, and chimneys in which we find them to-day.

In the case of *lodes*, *contact-deposits*, *flats*, and *chimneys*, the minerals have been introduced by *infiltration*, *condensation*, or *sublimation*.

Infiltration.—The earth, consolidating by degrees through prolonged ages, began to generate an atmosphere of its own, the vapour in the atmosphere, following the physical laws in existence to-day, descending as moisture and rain upon the earth; contemporaneously with the formation of this atmosphere the enormous amount of moisture which must have condensed from the cooling of the heated vapours had, in all probability, formed the sea.

As we have already seen, the moment moisture and rain commenced to fall upon the earth, the wearing-down process began and the deposition of stratified rocks took place; the minerals and metals then on and near the surface would be transported with other loose material and would be deposited

in layers and beds in the sea, in crevices and hollows, on alluvial flats—wherever, in fact, the water transporting them would, by gravity, flow.

We have seen that in process of time the stratified rock-systems became tilted and fissured by the disturbing influences within the earth, and we know that these great movements must have been productive of, and accompanied by, considerable heat; the water upon the globe had doubtless already dissolved a large quantity of minerals, holding them in chemical solution, but when heated by contact with the vulcanic energy, its power of dissolving minerals out of their matrix was greatly increased, and all waters upon the earth were probably highly charged with mineral matter; but when the vulcanic energy was expended, the waters began to cool and evaporate, the contained minerals being deposited along the floors and on the walls of whatever hollow or fissure they occupied; such is the theory of infiltration, very briefly described.

Condensation.—The water which found its way about the surface of the earth would naturally rush down any gaping fissure or crevice; coming in contact with heated and molten minerals in the seething mass below, it would reascend as *mineralised vapour*. As it ascended it would come in contact with the cold rocks above and through which it passed, and, *being condensed*, would deposit its contained minerals along the walls of whatever fissure, crack, or crevice it traversed.

Sublimation.—It will readily be allowed that gases would rise through every minute crack in the crust of the earth from the molten or red-hot mass beneath, such gases being evolved from the heated minerals. As they ascended and came in contact with the cooler rocks above, they would condense, *precipitating themselves* in a similar manner to that explained under 'condensation.'

Such are, in short, the generally accepted theories regarding the origin of minerals in *lodes, contact deposits, flats, and chimneys*.

An interstratified mineralised bed has, in nearly all cases, acquired its mineral character by precipitation from the water

which deposited it, and which contained the mineral in solution. The water may have obtained its mineral character either from vents or pipes communicating with the interior, or from mineralised strata through which it had percolated.

In other cases it would appear that percolating water, containing minerals in solution, has invaded certain strata, to the exclusion of those above and below, and has precipitated its contained minerals in the one stratum only. In such a case it would seem that some affinity must have existed between the minerals in solution and the minerals in the rocks forming the stratum; or that certain influences, such as organic acids, were at work in the one stratum and not in the others, in order to bring about the precipitation; or, again, that the porosity of the mineralised stratum was so great, and that of the containing strata so small, that the waters passed only through the now mineralised stratum.

Seas and lakes, as we have seen, often hold large quantities of mineral salts in solution. Evaporation has, for the most part, been instrumental in causing precipitation of their minerals, such precipitation having resulted in the formation of some very large deposits of valuable mineral strata.

As has been pointed out (page 145), *pockets* of ore are most common in limestone, or in rocks heavily charged with lime. Such rocks are readily soluble, and percolating water has been instrumental in dissolving out portions, leaving larger or smaller cavities. These cavities have been charged by mineralised waters, which, having settled temporarily in the cavities and hollows, have been thereby aided in precipitating their contained minerals.

We have remarked that in addition to surface *detrital* deposits there are also surface *chemical* deposits. The chapters on the modifying influences at work upon the earth's surface will enable the student to understand the origin of the former. With regard to the latter, some iron ores, manganese ores, common salt, gypsum, nitrates, probably some alluvial gold, and gems have, among others, been precipitated and deposited upon the earth's surface. Organic acids and electrical agencies have often assisted in their precipitation or deposition, but as their mode of occurrence is

so extremely varied, is so much dependent upon local surroundings, and requires considerable scientific knowledge and investigation, an elaborate description of the processes resulting in such deposits would be out of place in this work.

Shoots or shutes.—Rarely are lodes found in which the metal is equally distributed throughout the vein. In some cases the richest part is in the centre; in others, it is the hanging wall, and in others the foot wall. A peculiarity of gold-bearing quartz lodes is the tendency of the metal to arrange itself in certain *zones*, *shoots*, or *shutes*, as they are termed. No perfectly satisfactory explanation can be given to account for this phenomenon, but it can be conjectured that, whether the metal were brought into the vein by infiltration, by condensation, or by sublimation, the gold-laden agent, whether water, vapour, or gas, would naturally pass down or up the easiest passage, avoiding those portions of the fissure which offered the more difficult route.

Barren quartz lodes.—Perfectly barren quartz lodes are often found close beside highly metalliferous ones. In part, this peculiarity may be due to the fact that the fissures were filled before the mineralised waters or vapours were ascending or descending through the strata; but the geological age of the lodes and the occurrence of pyrites is generally believed to govern this peculiarity. The older quartz veins are the more productive, those of Carboniferous age being nearly barren, while Silurian quartz is the great repository of gold.

'The productiveness of the quartz reefs seems further to depend upon the nature of the strata with which they are associated. As a rule the quartz reefs are auriferous as they pass through hornblendic or porphyritic rocks, and cease to be so when they enter schists, or the metal does not then occur in paying quantities. Diorite is also associated with the best paying lodes.'[1]

Affinity between certain metals and rocks.—It is useful to remember that the best lodes of certain metallic ores are found to be associated more or less with certain rocks.

Thus:—

Granyte contains good tin lodes.

[1] Davies, *Metalliferous Minerals and Mining*, page 67.

Hornblendic rocks contain good cinnibar lodes.

Lower Silurian slates contain good copper lodes.

Upper Silurian slates contain good gold lodes.

Carboniferous limestones contain good silver, lead, and zinc lodes.

In Cornwall the copper lodes invariably turn to tin as the granyte is reached, and although no hard-and-fast line can be drawn, *it will be generally found that the nature of the strata through which a mineral vein passes alters the nature and productiveness of the latter.*

CHAPTER IV

Geological History

In the first chapter of this section we considered the various natural internal and external influences which have been, and ever are, at work in modifying the structure and appearance of the earth's crust. In the second chapter we investigated the various structures which have been induced in the rocks of the earth, and in the third chapter we alluded briefly to the nebular hypothesis of the origin of the planet we inhabit. We must now consider in outline the various great changes and events which have taken place in geological history, and which we must read by the light of the records which the rocks of the earth present to us at every point.

All speculation concerning the *very first* rocks of which the crust was formed is lost in the distance of time which must have elapsed since the first consolidation of our planet as a globe—a period so immense (it has been computed at many millions of years) that the mind of man almost fails to grasp the vastness of the record with which he is confronted. We can but acknowledge that the world was 'in the beginning,' and although we can hardly hope to connect, in point of time, the oldest stratified rocks with the earliest consolidated crust, we *can*, by patient study and observation, trace the geological history of the world back into ages still enormously remote from the present.

Now, although it is true that we have in no place bored more than 4,000 feet into the solid crust of the earth, we can, owing to the tilting, folding, fissuring, uprising, and subsidence of different portions of the earth's crust at various periods, examine a thickness of rocks of quite 100,000 feet.

Geological history has been divided into several periods;

the periods have been divided into systems, and the systems into formations and subdivisions. These periods are designed to denote certain epochs in geological history, as they appear by their contained fossil remains to mark a gradual improvement and evolution in the forms of plant and animal life present upon the earth. These periods have come to be used to denote not only a certain particular group of formations, but a certain *period of time* also, although we cannot, of course, fix the distance of that time by any exact number of years. Thus, we speak of Silurian rocks, and of the Silurian period; or of Permian sandstone, and of fossils of Permian age; and so forth.

Geologists are still not agreed as to the best classification of the geological period, but the one here given is that of a most eminent geologist,[1] and is one of the latest and simplest.

The periods are five in number, namely:—

1. *Archæan*; embracing the periods of the earliest rocks, wherein no traces of organic life occur (*Azoic*).

2. *Palæozoic*, or *Primary*; including the long succession of ages during which the earliest types of life existed.

3. *Mesozoic*, or *Secondary*; comprising a series of periods when more advanced types of life flourished.

4. *Cainozoic*, or *Tertiary*; embracing the ages when the existing types of life appeared, but excluding man.

5. *Quaternary*, or *Post-tertiary and Recent*; including the time since man appeared upon the earth.

Azoic means *without life.*

Paleozoic means *ancient life.*

Mesozoic means *middle life.*

Cainozoic means *recent life.*

These periods, with their systems and formations, are arranged in tabular form on page 156. The student is advised to commit them to memory.

Commencing with the most ancient rocks, and proceeding through each successive period and system to the most recently formed strata, let us endeavour, by means of the records they bear, to get some idea of the successive geological changes which the earth has witnessed.

[1] Professor Geikie, LL.D., F.R.S., *Class Book of Geology*, page 305.

Tabular Arrangement of Rock Systems.

Period	System	Formations
Quaternary or Post-tertiary	Recent and Prehistoric	In process of formation.
	Pleistocene, or Glacial	Glacial.
Cainozoic or Tertiary	Pliocene	Varying formations.
	Miocene	" "
	Oligocene	" "
	Eocene	" "
Mesozoic, or Secondary	Cretaceous	Danian. Senonian. Turonian. Cenomanian. Gault. Necomanian.
	Jurassic	Purbeckian. Portlandian. Kimmeridgian. Corallian. Oxfordian. Bathonian. Bajocian. Liassic.
	Triassic	Rhætic. Keuper, or Upper Trias. Muschelkalk. Bunter, or Lower Trias.
Palæozoic, or Primary	Permian	Upper Red Sandstone. Magnesian Limestone. Marl Slate. Lower Red Sandstone.
	Carboniferous	Coal-measures. Millstone Grit. Carboniferous Limestone Series.
	Devonian and Old Red Sandstone	Devonian or Marine Type. Old Red Sandstone, or Lacustrine Type.
	Silurian	Upper Shales and Limestones. Lower Grits and Flags. Primordial or Cambrian { Upper Shales and Flags. Lower Grits and Slates.
Archæan (Azoic)	Archæan	Crystalline and Schistose Rocks.

ARCHÆAN.

From beneath the oldest fossiliferous rocks there have been pushed up at various periods of the earth's history certain ancient crystalline azoic rocks. In what manner these rocks were originally formed we have no means of telling; they may, indeed, be proved in course of time to be of much later origin than is generally supposed, and their ancient appearance to have been induced in them by some cause of which we have no knowledge; but for the present their highly crystalline texture, their imperfectly preserved lines of stratification, their highly schistose character, and the fact that they have up to the present been found unfossiliferous have caused them to be regarded and classed as the most ancient of all the rocks of which the earth's crust is composed.

The Archæan rocks are chiefly gneiss, quartzyte, and various schists (mica s., talc s., chlorite s., hornblende s., actinolite s.) and serpentines. All these rocks have been contorted, ruptured, and compressed by some enormous mechanical power, probably assisted by great heat. No division of them into systems is of any practical value, as their order of succession varies in so many districts; they occur in disturbed ground and mineral veins, and gems may be looked for in their vicinity.

Gneiss, which is the most widely distributed rock of the series, graduates into granyte; and it would be well to follow a granyte which showed signs of graduating into gneiss in the direction of the increasing gradation, in order that the centre and whole area, in fact, of the disturbance which had foliated the granyte might be examined for mineralised fissures.

Rocks of Archæan age are widely distributed over the world, giving a rugged and barren appearance to the landscape. They occur in the Alps, Pyrenees, Himalayas, Cordilleras, Atlas, Alleghanies, Drakensberg, Rocky, and other mountain ranges, and are also found in China and Japan.

Fissured and overlain by dykes and sheets of granyte, diorite, felsyte, porphyryte, and other igneous rocks, they

often contain valuable mineral deposits. Tin, copper, hematite, wolfram, blende, and some of the rarer metals, such as uranium, are often found in these rocks. Graphite or plumbago is a common and valuable product, while fine-grained

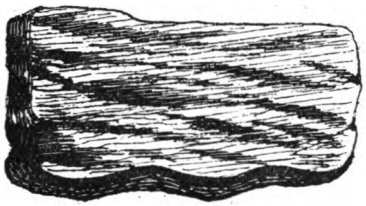


FIG. 66*a*.—Gneiss.

FIG. 6.—Block of Flexured Gneiss (from a photograph).

and well-marked serpentine, as well as asbestos, which both occur in these rocks, are valuable if of good quality. Gold and cinnabar are found sparingly, while, of gems, diamonds, rubies, emeralds, garnets, topaz, and tourmaline, among others, often occur in veins and cavities in Archæan rocks.

PALEOZOIC.—SILURIAN.

The Silurian system—so called after the Silures, an ancient British tribe who lived on the borders of England and Wales, where these rocks are typically developed—is the oldest fossiliferous system with which we are acquainted. In the rocks belonging to this system we get our first glimpse of the ancient animal and plant life upon the earth.

The system is conveniently divided into two groups, both of which contain valuable metalliferous deposits, and are therefore well worthy the attention of prospectors and explorers: (*a*) the Lower, or Cambrian group (*Cambria*, Wales); and (*b*) the Upper, or Silurian group.

The *Cambrian group* has been divided into the following formations:—

Upper	Tremadoc slates; dark and earthy, with pisolitic iron ore. Lingula flags; micaceous flagstones.
Lower	Menevian flags, slates and grits. Harlech, purple, red and grey flagstones, sandstone. Grits and conglomerates.

The Cambrian group is well developed in Wales, Ireland, Scotland, Scandinavia, Canada, North America, Victoria (Australia), and South Africa. It imparts to the country a bold, rugged appearance, the weathered slates and flags of the system towering up into lofty pinnacles or splintering off into jagged gorges and ravines.

From the nature of the rocks, their widespread occurrence and their fossil remains, we can form some idea of the earth's appearance in the far-off days when they were deposited.

From the Archæan land, which probably existed in proximity to the poles, the rains and tides washed down into shallow seas, which must have covered great areas of the world's surface, huge quantities of detritus; the rippling waters rolled and ground these particles finer and finer, spreading them out in far-reaching sheets on muddy flats, or beneath its own surface. Lowly seaweeds grew in the muddy shallow waters, while worms and the lowest forms of life burrowed in and dwelt upon the marshy land. The earth must have had an appearance of great desolation, with its huge tranquil seas and treeless flat land. The rain fell and spattered; the tide ebbing and flowing left ripple-marks on the soft mud by the shore; the sun baked and cracked the flat surface; but beyond a few crustaceans, with here and there a colony of worms, there was no living creature to break by sound or movement the deathly stillness of the earth.

Some typical fossils of the system, by which it may be determined, are here given.

The entire Cambrian series has been broken through, disturbed, and faulted by dykes and sheets of granyte, por-

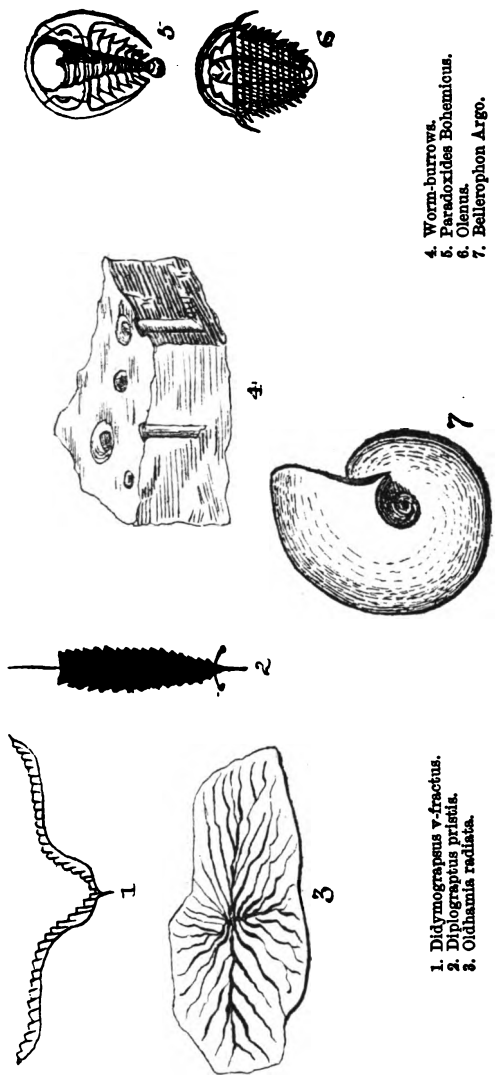


FIG. 67.—Cambrian Fossils.

phyryte, felsyte, and dioryte, and is often traversed by mineral veins. Recognising any of the rocks of this group

the prospector should always carefully examine the series; they yield, among others, ores of iron, copper, tin, zinc, antimony and silver; valuable phosphates are sometimes found, while serpentine and slates of good quality are common products of these formations.

The *Silurian* or *Upper group* consists of—

Upper Silurian shales and limestones.
Lower Silurian grits and flags.

The chief interest which this group has for the prospector is in its gold deposits. Sir Roderick Murchison, the eminent geologist and mineralogist, says that 'the most usual original position of gold is in quartzose veinstones that traverse altered palæozoic slates, frequently near their junction with eruptive rocks.

'The stratified rocks of the highest antiquity, such as the oldest gneiss or quartz rocks, have very seldom borne gold, but the sedimentary accumulations which followed, or the Silurian, Devonian, and Carboniferous (particularly the first of these three), having been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by the influence of igneous agency or other causes, have been the *chief* sources whence gold has been derived.'

Since Sir R. Murchison's day gold has been found and worked profitably in many other formations besides Silurian, but it is quite questionable still if the *chief* sources of gold be not in Silurian rocks. Payable gold in quartz, and quartzyte veins running through them, has been found in Europe, Asia, America, and Australasia; while, latterly, large gold deposits have been discovered in Silurian strata at De Kaap, and less developed but equally promising ones are being explored in the Murchison range (Silurian) slates in the Transvaal, South Africa.

For the most part the conditions obtaining over the earth's surface during the deposition of Silurian strata must have been very slightly different to those in the Cambrian time; the same wide-reaching muddy flats, the same shallow seas; but greater *variations* of climate and atmospheric change, as well as of altered conditions of animal life, are shown by the

constantly varying beds of shelly limestones, shales, grits, coral beds, and sandstones.

In addition to the graptolites and trilobites of the Cambrian group, we get as typical fossils of Silurian time the following, among others :—

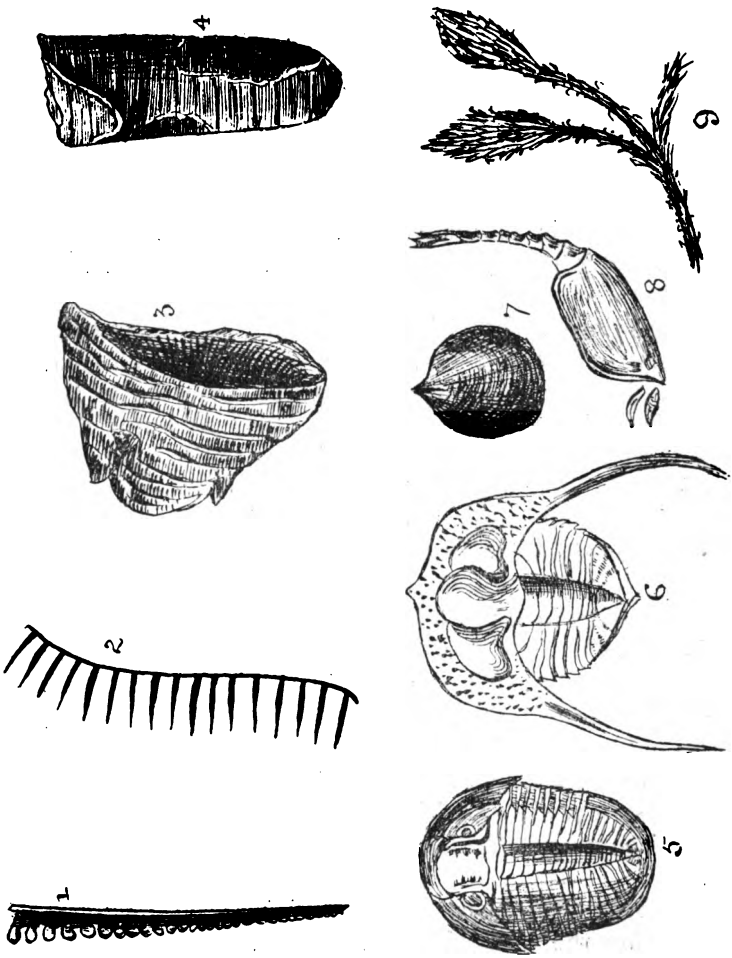


FIG. 68.—Silurian Fossils.

1 and 2. Graptolites. 3. Rugose Coral. 4. Orthoceras. 5 and 6. Trilobites. 7. Lingulella. 8. Phyllopod (Crustacean). 9. Lycopod (Plant).

The prospector finding any of these may be sure that he is among Silurian rocks.

Well developed in all the great continents of the world,

Silurian strata present much the same physical features as do the Cambrian. Among the eruptive rocks, which have tumbled and tossed the once flat strata into endless variety of hill and dale, are granyte, felsyte, and various greenstones.

In addition to the undoubted chances that there are of finding auriferous quartz veins in these strata, the prospector will do well to examine carefully any series of these rocks which he may come across. Ores of mercury, tin, copper, silver, lead, zinc, and antimony, are found in them; while good lime can be obtained from the limestones in the upper series.

Generally speaking, the Silurian system is not only of great interest to the scientist, as presenting the earliest records of organised beings upon the globe, but it is also of the highest commercial importance, containing many of the baser, as well as the noble metals, in veins and deposits within its strata.

DEVONIAN AND OLD RED SANDSTONE.

There is no very decided line of demarcation between the Upper Silurian and the lower Old Red Sandstone formations; they graduate very gently from one into the other, and but for the marked differences in the fossil remains, more especially those of the vegetable kingdom, the one might readily be mistaken for the other. A careful examination, however, of both rocks and fossils will tell of an altered condition of the life and geography of the world during the periods of their deposition.

The system has been divided into two subdivisions; the lower of the two, or the *Old Red Sandstone* proper, represents a series of freshwater lake deposits; the upper subdivision, or the true *Devonian*, includes the deposits formed by and under the open seas of the period.

From the distribution of these two types it would seem that the wearing-down processes which had been at work upon the Archæan rocks during the Silurian age had resulted in the depositing of such large amounts of mud, sand, and other detrital matter, that portions of the shallow Silurian

seas had been cut off and lakes formed by the gradual extension of ridges and banks resulting from this immense detrital action. These lakes were salt, or at least brackish. But elsewhere, away from the sea, parts of the land were already sinking and others rising, with the result that the waters pouring off the high land at the poles rushed into the hollows, lakes of fresh water and very large areas being formed contemporaneously with the salt ones.

Into these lakes were poured vast quantities of sand, silt, and gravel, while the now greatly diminished sea would appear to have been deeper, and, from the evidences of its corals and other fossils, to have been peopled by a much larger and more varied population.

The world began to bear a more diversified appearance; sea and land began to arrange and distribute themselves with greater variety; while the land itself, although flowerless, was partly covered with a mossy carpet, ferns growing in cool and shady, and reeds in marshy places.

In addition to the fossils which tell us of life on land and in sea, ripple-marks point to tidal waters, and rain-prints to the occurrence of showers; the presence of preserved terrestrial plants and freshwater fish in the marine deposits shows us that rivers coursed their way through the valleys, carrying in flood-time the uprooted plants and trees into the ocean, and often gathering sufficient force to bear fish from their home in the fresh waters far out into the salt.

Apart from fossil indications, the whole system is easily recognised by the brightness of its colours; grey, yellow, brown, chocolate, and bright red of various tints alternate throughout the whole thickness of these strata, some 10,000 feet of which have been examined. The following are the formations of this system in their order of succession, the oldest being at the bottom :—

Fine-grained yellow sandstones.
Marine limestones, mottled grey and red.
Coarse conglomerates, red, yellow, and grey.
Red sandstones and conglomerates.
Grey sandstones, with pebbles and conglomerates.
Micaceous flagstones and tilestones (sandy slates).

One or other of these formations (and often the whole series) is found all over the world; they impart to scenery a soft and rounded appearance, great diversity of hill and dale, and vivid colouring; some of the most beautiful mountains in the world (Table Mountain in South Africa and the Ochils and Sidlaws in Scotland) belong to this system.

Typical fossils by which the series may be recognised are given in fig. 69.

The Devonian and Old Red Sandstone system has been greatly upheaved by vulcanic agency; granyte, felsyte, porphyryte, and various greenstones and dolerytes frequently overlying and intruding the strata; this vulcanic energy is believed to have commenced and expended itself at the close of the Devonian and before the commencement of the Carboniferous epoch, the laying down of the successive strata of the former system having apparently proceeded with great tranquillity.

Of dykes and mineral veins there are comparatively few, and although quartz is a common veinstone, it is not infrequently barren.

The prospector will not find this system so productive as the preceding one. Veins of copper and barytes are found and profitably worked, while lead and zinc are not uncommon in the limestones; gold is found in quartzose veins; and silver occurs sparingly with lead. Siliceous gems, such as agates, chalcedonies, cairngorms, and cornelians, as well as topaz, are found in cavities and in crystallised veins traversing these strata. From the limestones what is called *Devonshire marble* is obtained, and is largely employed in architecture.

The auriferous conglomerates of Witwatersrandt in the Transvaal have, on scanty evidence, been placed among the Devonian rocks; although a prospector would do well to examine Devonian conglomerates for gold in the future, it is much more likely that the above-mentioned series belongs to the mesozoic period.

Generally speaking, the Devonian and Old Red Sandstone groups are of the greatest interest to the scientist, giving as they do a glimpse of the first great diversity of the earth's surface, the commencement of the arrangement of sea and

land, the beginning of terrestrial vegetation, and the presence of freshwater life. They form also a splendid guide for the

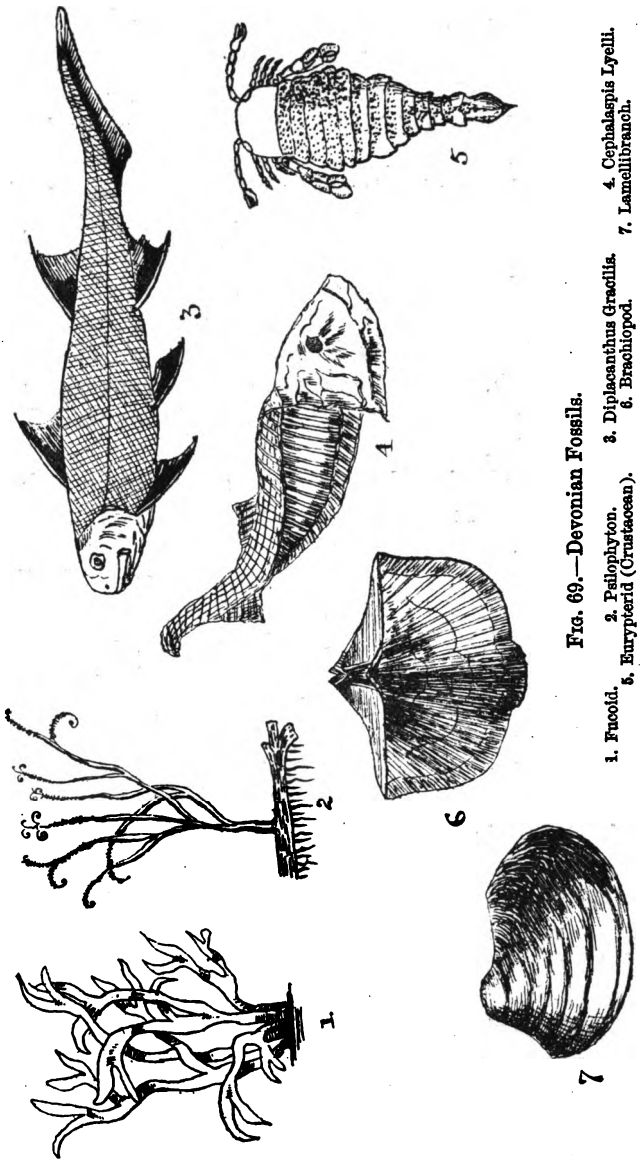


FIG. 69.—Devonian Fossils.

1. Fucoid. 2. Psilophyton. 3. Diplacanthus Gracilis. 4. Cephalaspis Lyelli.
5. Eurypterid (Crustacean). 6. Brachiopod. 7. Lamellibranch.

prospector, lying between the mineral deposits in the Silurian system below and the immense wealth of the Coal-measures above.

THE CARBONIFEROUS SYSTEM.

The Carboniferous system, so called from the Latin *carbo*, in allusion to the coal-beds which are here typically displayed, is one of the most important of all systems.

Like the last, this system has been divided into two groups:—

The Lagoon Group	Alternating red and grey sandstones and grey and yellow shales, fireclays, coals, ironstone, and limestone.
The Marine or Estuarine Group	Millstone grit (grits, quartzose sandstones, flags, and shales). Carboniferous limestone (marine limestones and shales and thin coal-seams).

The Carboniferous period marks a most decided change in the geography and life of the world. The limestones at the bottom of the system are sometimes over 5,000 feet thick, and are formed for the most part of the remains of corals and crinoids; these relics point to clear seas, upon the bottom of which flourished countless myriads of these creatures and plants. On the margin of the seas and lagoons a luxuriant vegetation existed, which was from time to time submerged by the waters, and, being covered by successive layers of detritus, was compressed and mineralised, forming the valuable beds of fuel which we call coal.

That the seas and lagoons of the Carboniferous period were shallow is proved by the frequent alternation of these coal seams with sandstones, fireclays, and conglomerates, and the numberless remains of terrestrial creatures found in the limestones; sun-cracks and ripple-marks among them testify also to land which was in the proximity to, but not under, water.

How, then, is the great thickness of these aqueous deposits to be accounted for? It is clear from the fossil evidences in the limestones that the same class of corals which helped to

form the bottom strata are also present in the topmost; apart from the fact that the coral does not build in deep water, it is known that creatures of the same nature could not live near the surface and at a depth of 5,000 feet; the only solution of these great thicknesses of strata *deposited under water* is to be found in the supposition that the land was gradually sinking during the period of their deposition, so that as fast as one stratum with its contained fossil remains sank, another one was deposited above it.

The sinkage of the land did not, however, progress constantly, but at well-marked intervals. The constantly recurring seams of coal with their underlying seams of fireclay, which represent the soil upon which the vegetation forming the coal grew, point to alternate periods of subsidence and rest; how long these periods of rest lasted we have no means of judging, but they must have been sufficiently long to enable a thick mass of vegetation to grow again in the place of the one destroyed.

The Millstone-grit formation probably represents a period of almost incessant subsidence, for the imbedded seams of coal are thin and scanty; the alternating periods when the rests must have been longest are represented by the lagoon type. The prolonged subsidences which had taken place during the period occupied by the Millstone grit had, doubtless, caused inequalities in the surface of the land into which the sea entered, forming lagoons. Round these lagoons, and perhaps in their shallow waters, there sprang up a most luxuriant vegetation; pine-like trees of huge size and beautiful foliage grew side by side and among gigantic ferns and reeds; the jungle was alive with myriads of insects and flies which settled on and lived upon the verdant foliage; but when all the plant life was at the zenith of its beauty the land once more began to sink, the rushing sea swirled in, and, laden with sand, gravel, and mud, swept round the trunks and branches of plants and trees, and, aided by the subsidence, soon obliterated the forests. As in the case of the ocean-formed limestones and the Millstone grit, so in the lagoon-formed series of true coal-measures, a period of subsidence was succeeded by a period of rest, in which the shallow

lagoons were silted up and the vegetation crept out over the swamp once more and flourished for a season.

From the fossils which have been preserved in the coal-

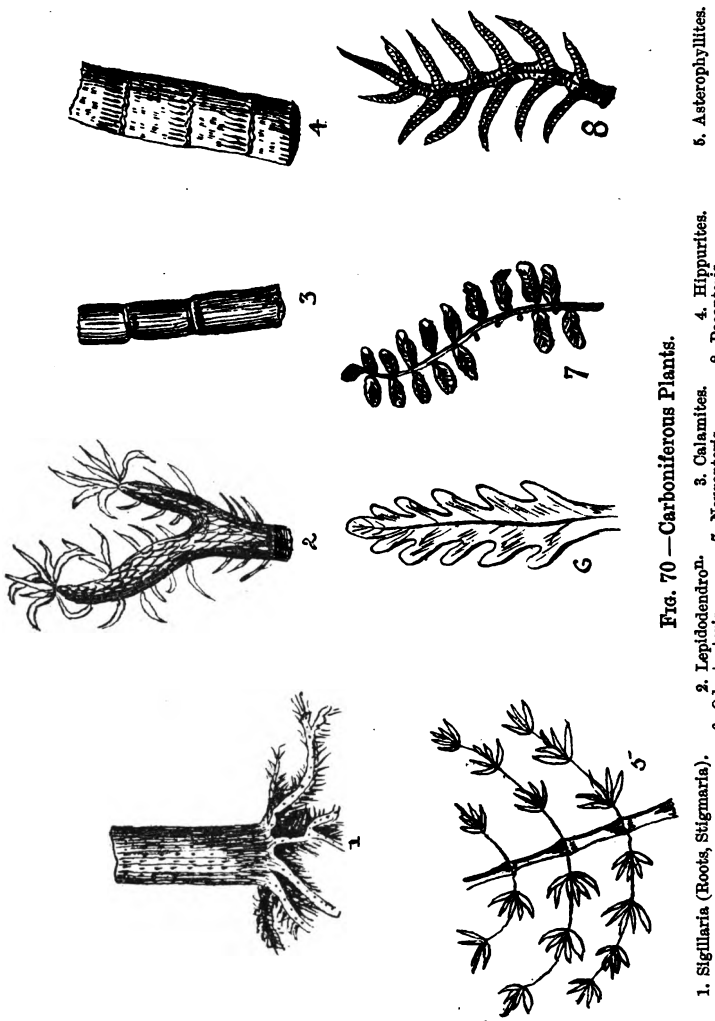


FIG. 70.—Carboniferous Plants.

1. Sigillaria (Roots, Stigmaria). 2. Lepidodendron. 3. Calamites. 4. Hippurites. 5. Asterophyllites. 6. Odontopteris. 7. Neuropteris. 8. Pecopteris.

seams we know that the vegetation, although somewhat monotonous in colour, and nearly flowerless, must have been of exceeding richness and beauty of form. Beetles, locusts,

and crickets teemed in the woods, while toad-like creatures and salamanders inhabited the marshy jungles; fishes

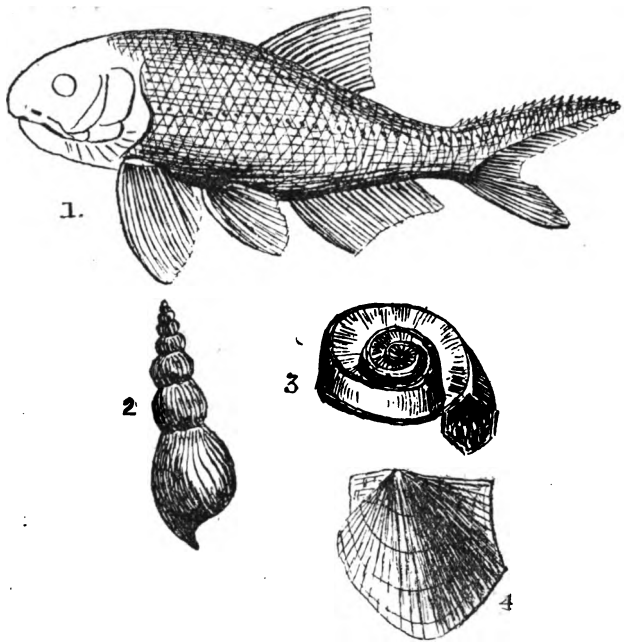


FIG. 71.—Carboniferous Fossils.

1. Amblypterus. 2. Loxonema. 3. Euomphalus. 4. Ariculopecten.

swarmed in the seas and lagoons, while crinoids, corals, urchins, and various shelled creatures congregated in numbers in favourable places.

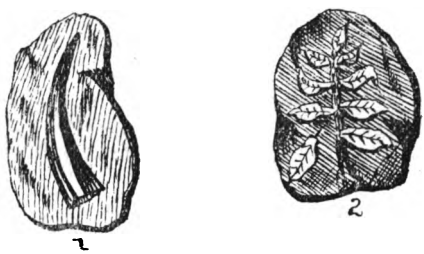


FIG. 72.—Septaria: Nodules of Ironstone enclosing

1. Tooth of Rhizodus. 2. Pinnule of Neuropteris.

Among the Coal-measures layers of nodules of clay carbonate of iron ($FeCO_3$) occur, sometimes in great numbers; the car-

bonate of iron appearing to be segregated around some organic nucleus.

Such nodules are known as *septaria*. During solidification they shrink, and the cracks formed by the contraction are filled up with carbonate of lime.

The physical aspect of the Carboniferous system to-day is much varied; within the range of the Carboniferous limestone we may see sturdy hills, rather barren than verdant, and rocky glens; but the scenery of the Millstone grit and the Coal-measures is generally tame and uninteresting, while the soil is poor and unprofitable for agriculture.

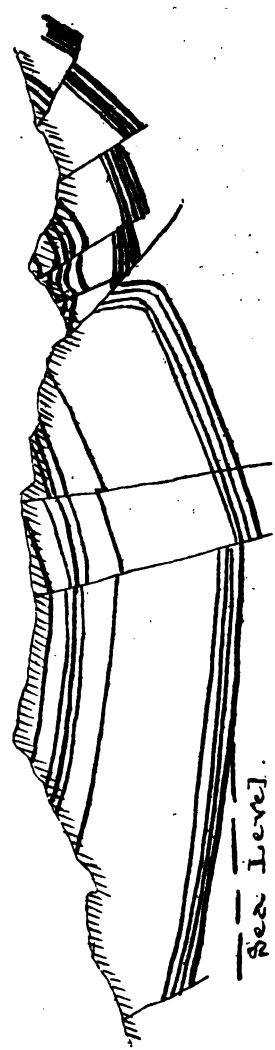


FIG. 78.—Grand Combe Coalfield.

Carboniferous strata show evidences of considerable volcanic and vulcanic activity; indeed, we cannot suppose a constant subsidence in one part of the system without an upheaval in another. Rhyolyte, doleryte, dioryte, and many augitic and olivine rocks are common; dykes of one or other of the greenstone rocks have been proved to fault our coal-beds with varying degrees of intensity.

The Carboniferous system is well distributed over the world; coals belonging to it are worked in England, France, Belgium, Bohemia, Russia; in North America, Canada, Japan, New South Wales, and New Zealand. In the Cape Colony carboniferous coal is worked, but the Natal and Transvaal coals would seem to be of later date.

In addition to coal, which is always valuable, carboniferous

strata are productive of paraffine, ozokerite, bitumen, and asphalt. Lead, often silver-bearing, occurs in the limestone, as do ores of zinc and antimony, the latter being sometimes silver-bearing also. Copperas is obtained from the iron pyrites, alum from some of the shales, and iron is commonly found and worked in the Coal-measures; the fireclay beneath the coal-seams makes splendid bricks, and the grits good building-stone. Gold in carboniferous strata is rare, and quartz reefs traversing them too often barren. Native mercury sometimes occurs in the shales.

Although not rich in the precious metals, the Carboniferous system is of immense value to man; in these days of competition, when time means money, steam is the great factor in all great industries; without full application of the uses of steam no country prospers to its possible extent, without coal steam can hardly be profitably applied. The Carboniferous system does not possess gems of lustre, but it *does* possess, in an eminent degree, the most valuable of all gems—the black diamond, coal.

THE PERMIAN SYSTEM.

Between the Carboniferous and Permian ages a vast change took place in the geography of the world. The alternate periods of subsidence and rest which resulted in the periodical burial of the carboniferous vegetation gave place to upheavals of great magnitude and force. Dykes and outbursts of various igneous rocks testify to the greatness of the movements which effectually obliterated the lagoons and swamps of the Carboniferous period.

The system which is named *Permian*, from the province of Perm, in Russia, where it is typically developed, consists of the following formations:—

Upper red sandstones, clays, and gypsum.
Magnesian limestone; yellow and white.
Marl slate (*Keuperschiefer*); hard and brown.
Lower red sandstones with conglomerates and breccias.

At the bottom of the system there appear coarse angular *aqueous* breccias and conglomerates of all sizes. These must

have been denuded from some Archæan rocks, which were probably standing in prominent outline above the Carboniferous seas; on these were deposited a great thickness of sandstones, coloured bright red, and cemented by earthy peroxide of iron; upon these are marl slates and shales, which are in Germany impregnated with copper pyrites, and are called in that country *Keuperschiefer*, or copper slate; a thickness of several hundred feet of magnesian limestone follows, and the whole is capped with alternating layers of sandstones, marls, and gypsum-bearing strata.

It is believed that the Permian epoch represents a period of comparative quiet over the face of the world. The eruptions which took place, as we have said, at the close of the Carboniferous period had doubtless elevated the land in great diversity of outline, and had been instrumental in forming inland seas. The presence of such large quantities of iron, gypsum, and salt, and of layers of nodules bearing strontium with lime carbonate, alternating as they do in such rapid succession, point to frequent though placid changes in the conditions which resulted in their deposition, and this deposition evidently took place in inland seas which were alternately evaporated by the sun's heat and replenished by fresh inpourings of water (see pages 115, 128).

The presence of salts of lime, magnesia, sodium, strontium, iron, and copper in these waters, accounts for the few fossils

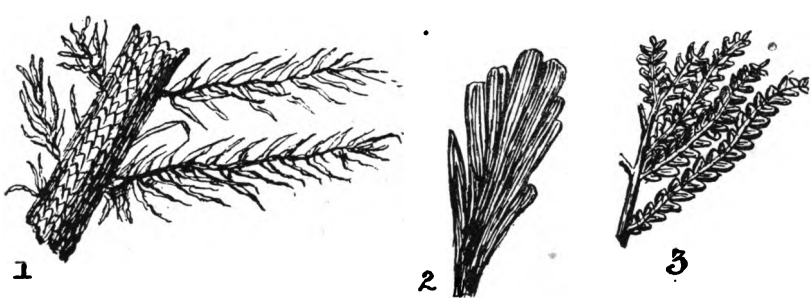


FIG. 74.—Permian Plants.

1. Walchia Piniformis. 2. Nægarathia. 3. Callipteris.

which are found in Permian strata as relics of the fauna of the period, but thin seams of coal tell us of the presence of a

vegetation which, although less luxuriant than that of the Carboniferous age, still flourished in favoured spots. From the fossils which have been preserved, however, we learn that a gradual change in the species of both plants and animals was taking place all over the world; Silurian and Devonian

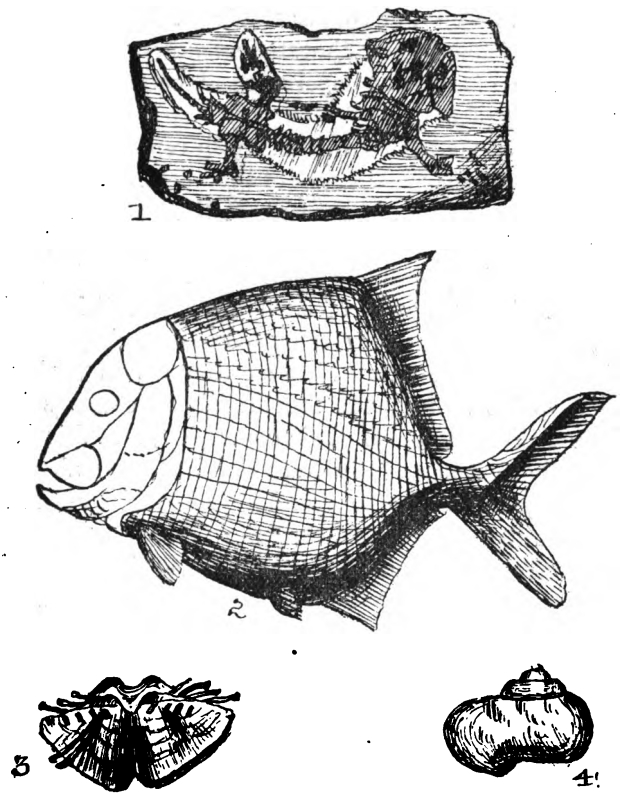


FIG. 75.—Permian Fossils.

1. Labyrinthodon. 2. Ganoid (Platysomus). 3. Productus Horridus. 4. Natica Leibnitziana.

species were now almost extinct, higher forms of both plant and animal life appearing in increasing numbers. As typical plant fossils those given in fig. 74 may be a guide to the prospector.

Of animal life the Trilobite had entirely disappeared, higher forms of crustacea taking its place. The first lizard

of which we have any record climbed the Permian trees; labyrinthodons and fish flourished on shore and in sea; while molluscs and other shelled creatures crowded together on rocks and over the ocean floor.

The various species given in fig. 75 will assist the student in correctly classifying Permian rocks.

The quietude which existed during the deposition of these strata gives to scenery in districts where they occur a tameness of outline and a flatness of surface, but vivid colouring has resulted from the earthy peroxide of iron with which the sandstones and marls of the series are impregnated. Very rarely indeed does the complete series of strata occur in unbroken succession, but they bear many physical features such as no attentive person can fail to note. Both sandstones and marls show bright green and mottled grey and green spots, often in well-defined layers; such spots being probably due to the alteration of the peroxide of iron into silicate of iron caused by organic acids. The magnesian limestone frequently assumes globular and other concretionary forms, as shown in fig. 76, of a piece of dolomyte from Sunderland, England.

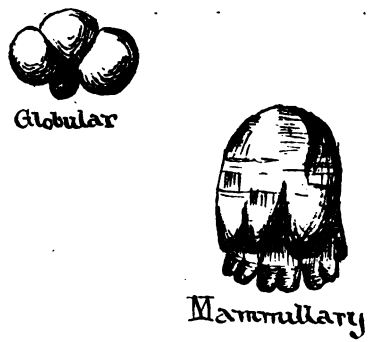


Fig. 76.—Dolomite Concretions.

To the prospector for precious metals the system is not of primary importance. The limestones when very fine-grained and compact are valuable for lithographic blocks, and from them all good lime can be obtained, while some of the sandstones make good building-material. In Germany the *Keuperschiefer* is largely worked for its ores of copper. Gypsum—hydrated plaster of Paris—and strontium ores, which are used for imparting a red colour to fireworks, are also found in considerable quantities.

The auriferous conglomerates of Witwatersrandt do not improbably belong to the Lower Red Sandstone of Permian age, but the fragments of fossils found hitherto (1889) are so

altered as to almost destroy recognition. The appearance of the country generally, of the conglomerates and their attendant coal-seams, much more nearly approaches Permian than Carboniferous strata, and inasmuch as the Permian period was one during which great quantities of minerals were deposited from waters and vapours, it is quite possible that the latter is the right period in which to locate these deposits.

The prospector is therefore advised to carefully prospect Permian conglomerates for gold. Coals of this age are worked in North America and South Africa, and although inferior to true carboniferous coals are still of considerable value.

MESOZOIC. TRIASSIC SYSTEM.

With the close of the Permian period we end the long succession of Palæozoic rocks, or those which contain fossil types of ancient life. We have seen that, in addition to these interesting relics of early life upon the globe, the various systems are of the greatest commercial importance to man, enclosing within their boundaries deposits of gems, the nobler and the baser metals, coal and other minerals. The periods which follow, although containing deposits of some commercial value, are chiefly interesting in showing the gradual appearance of higher forms of plant and animal life, more nearly approaching those of the present day, and also in explaining the growth of the successive strata as they appear to man at the present time.

The similarity of the physical conditions which existed during Permian time to those of the Triassic period is very marked, and it is chiefly in the greatly advanced types of animal and plant life that we recognise the appearance of a fresh epoch.

The name Trias, which has been given to this system, refers to the *threefold* division of the rocks in Germany, where they are well developed, the system being subdivided thus:—

Rhætic. Red, bluish, and green marls, black shales, salt beds, and thin coal-seams.

In Germany.	Keuper or Upper Trias	Various coloured marls, sandstones, and clays, with salt and gypsum beds.
	Muschelkalk.	Grey limestones and dolomytes, gypsum, and salt.
	Bunter or Lower Trias	Variously coloured sandstones and marls.

The deposits of gypsum and salt point, as in the Permian system, to large portions of sea water cut off from the main body of the ocean, but these deposits were much larger during Triassic than during Permian time. It has been pointed out (pages 115 and 128) that gypsum ($CaSO_4$) is less soluble than common salt (NaCl), and that it is precipitated when 37 per cent. of the water containing it in solution has been evaporated, while salt is only precipitated when 93 per cent. of the water containing it has evaporated. Knowing this, and being confronted by these Triassic beds of gypsum and salt, we naturally and rightly conclude that they were formed by precipitation from inland waters which were highly charged with these salts in solution; a rainless, floodless, or dry period would have the effect of causing evaporation of the water, and in process of time a bed of gypsum would be formed. The appearance of sandstone strata on the top of this tells us that an influx of sand-laden water stopped the evaporation and consequent precipitation of lime sulphate, only to be succeeded by another period of dryness, during which, so great was the evaporation, that first lime sulphate and then sodium chloride (salt) were precipitated until perhaps the lake was entirely dried up. Then came a change; the sea broke through the land, carrying with it great numbers and quantities of marine fauna and flora, spreading over the dry hollows of the lake-bed; remaining there for a season, the life it bore flourished for a while, fossiliferous limestone deposits being built up upon its floor. But once again the sea became surrounded and the marine plants and animals gradually died out; vegetation existing in the neighbourhood was either swamped in successive floods or else killed by saline vapours; the alternating periods of evaporation and moisture succeeded, and fresh beds of sandstone, salt, gypsum, potassium, and magnesium were deposited upon the bed and round the edges of the lake. Such

would appear to be, in brief, the history of these Triassic deposits.

Although doubtless the atmosphere was at times laden with brine and saline vapours in the proximity of these lakes, we have abundant evidence in the fossil remains, as well as in the thin coal-seams of the upper strata, of a rich and varied vegetation during the Triassic period. Cycads, palms, and

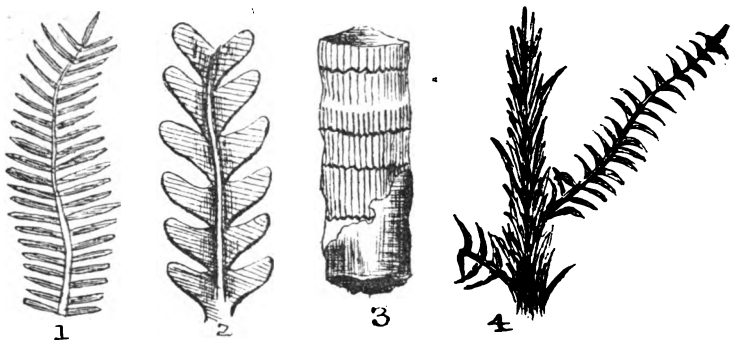


FIG. 77.—Triassic Plants.
1. Pterozamites. 2. Cycad. 3. Equisetum (Horse-tail Reed). 4. Walchia diffusus.

pines flourished, while calamites and equisetums (horse-tails) grew in abundance, and tree ferns found root in moist and shady places.

Around the margins of the lakes and by the seashore labyrinthodons, rhyncosaurus, and other strange, reptile-like creatures basked on the sands and mud, their footprints having been preserved in the sandstones and shales to tell us

FIG. 78.—Triassic.
Footprints of Cheirotherium or Labyrinthodon.

of their presence. Creatures resembling some of the Australian ant-eater tribe appear, from their fossil teeth and bones in these strata, to mark the advent of true mammalia upon the earth.

The limestone beds are full of fossils of marine fauna;

many of the older species appear in decaying numbers, and their place is taken, among others, by the following:—

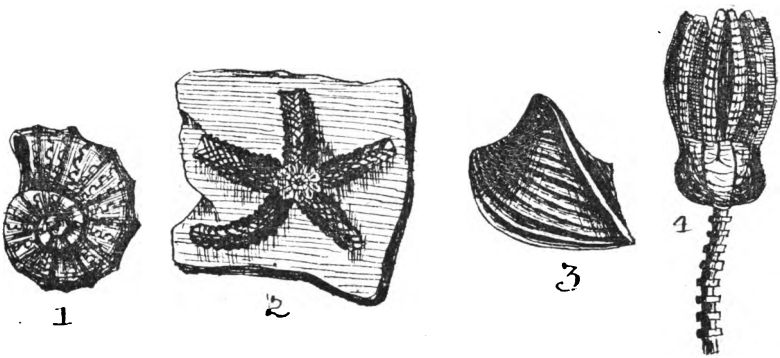


FIG. 79.—Triassic Fossils.

1. Ceratites Nodosus. 2. Aspidura (Star-fish). 3. Myophoria lineata. 4. Encrinus liliformis.

In addition to these fossils the prospector will have, as a guide to help him in the identification of this system, the vast beds of gypsum and salt and the shelly Muschelkalk limestone. Triassic rocks are largely distributed on the continent of Europe; they occur in Northern India, North America, at the Antipodes, and are well developed in Cape Colony. They were deposited during a period of comparative vulcanic quietude, and, from the nature of their stratification in wide, far-reaching sheets, give to a country where they form the surface rocks a flat and uninteresting appearance.

The chief commercial value of the system lies in the immense deposits of salts which were precipitated from the waters of its ancient basins. Sometimes quite pure, in white crystals, but more commonly tinged reddish and brownish by various contained impurities, these salt deposits are scattered over the world in immense sheets. In Germany, at the Stassfurt salt-mines, there is a bed of rock-salt upwards of 1,000 feet thick; it is separated into layers averaging 3½ inches wide by veins of anhydrite, or *water-less* lime sulphate, which are a quarter of an inch thick or less.[1]

[1] Professor Geikie, LL.D., F.R.S., *Class Book of Geology*, page 387. The student, from what has been said above concerning these deposits, can draw his own conclusions as to the conditions under which they were deposited.

In Cheshire, England, where salt-mining has been carried on for many years, there are two beds of salt; the upper of the two is 75 and the lower over 100 feet thick, the two being separated by about 30 feet of variegated marls.

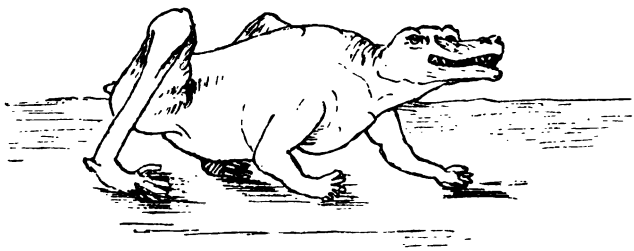


FIG. 80.—A Triassic Labyrinthodon.

The Triassic system produces good limestone, in which galena may occur, and various qualities of sandstone suitable for building.

THE JURASSIC SYSTEM.

This system, named after the Jura Mountains, where it is typically developed, includes the old systems known under the names of Lias, Oolite and Wealden.

The series record a period, or rather periods, of rapid but on the whole tranquil changes, not only of the geographical distribution of sea and land but also of climate. It is certain that in addition to wide and clear seas freshwater lakes and rivers were in abundance, and that as the sea and land began to arrange themselves with greater precision and more equanimity higher forms of animal life appeared upon the land and in the waters.

The following are the formations of this system, commencing at the bottom and working upwards:—

Lias.—A series of three layers (from the local pronunciation of which word the term *lias* is derived) of limestones. They contain fossil remains of the bones of huge animals, ichthyosaurus, plesiosaurus, &c., which probably lived in the seas and basked on the shores, watching for the smaller prey upon which they lived.

Deposited in the sea these lias beds tell of near land, on which vegetation existed, for the strata are crowded with plant fossils. The Lias is easily distinguished by its ribbon-like or banded layers of blue and grey limestone. Immediately above the Lias lies what used to be called the *Inferior Oolite*, but is now termed *Bajocian*, from Bayeux in Nor-

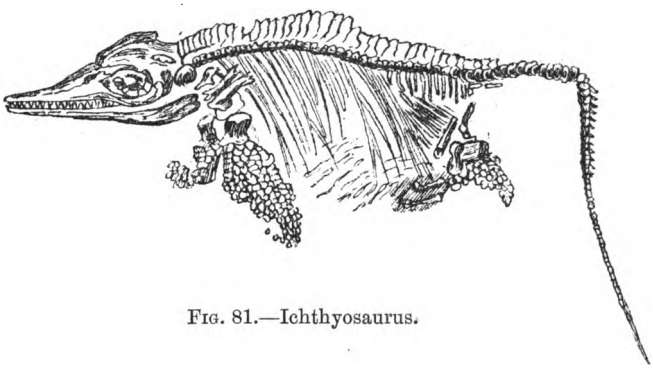


FIG. 81.—Ichthyosaurus.

mandy, where it is well developed. These strata would appear to have been deposited in an estuary or in brackish water. Clays, shales, sandstones, and shelly limestones, with thin seams of lignite, or brown coal, alternate very rapidly, telling of the constant flooding and silting up of the area over which they were deposited.

Bathonian, from Bath, in Somersetshire, is the name of the next formation, which has also been called the *Great* or *Bath Oolite*. Evidently of marine origin, these beds contain a remarkable number of fossils of corals, molluscs, and fishes.

The presence among these marine fossils of plant, insect, and animal remains, clearly points to rivers which swept through forests wherein the animals prowled in search of prey, and the insects fed upon the foliage of the trees.

Above the Bathonian comes the *Oxfordian* stage, which was once known as the *Middle Oolite*. It consists of stiff blue and brown clays upon a limy sandstone, which, though marine, were, to judge from their fossils, deposited in shallow quiet waters.

The *Corallian* formations, which come next in order, abound in coral remains, which clearly point to their deposi-

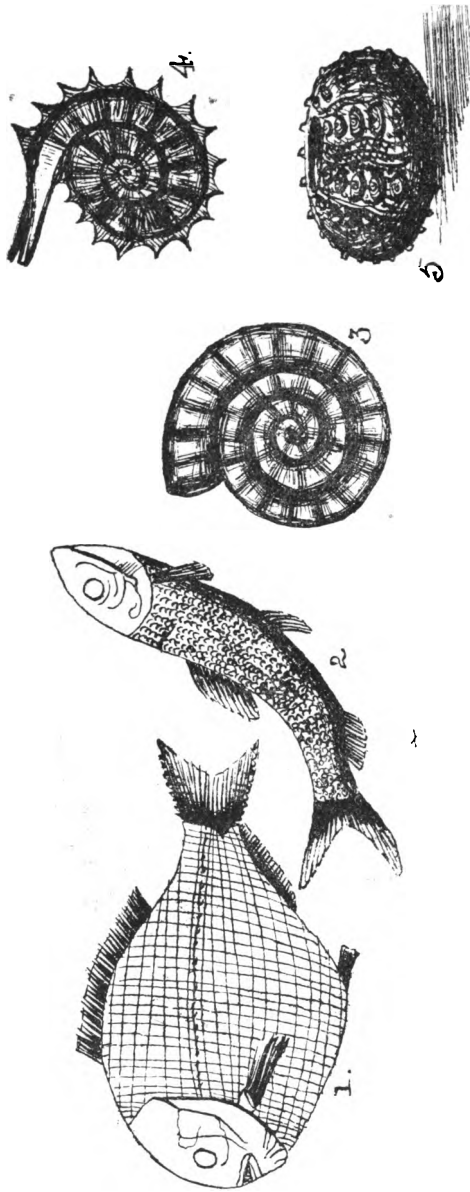


FIG. 82.—Jurassic Fossils.

1. Dapedius. 2. Leptolepis. 3. Ammonites communis. 4. A Jason. 5. Cidaris (Sea-urchin).

tion in clear, shallow seas, upon the bottom of which countless numbers of these creatures were ceaselessly busy in the construction of reef.

FIG. 83.—Jurassic Belemnite (Puzosianus).

Above this we come to the *Kimmeridgian* stage. Here we find a series of strata almost entirely formed of bituminous and carbonaceous shales and clays, telling us of estuaries rather than of deep seas. On the flat reaches of the land and

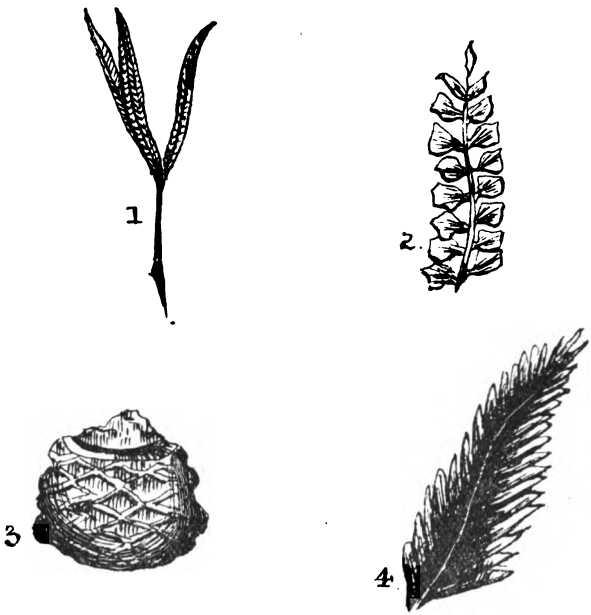


FIG. 84.—Jurassic Plants.

1. Glossopteris. 2. Cyclopteris. 3. Cycad. 4. Pterophyllum.

in the marshy ground beside the water there was doubtless a great deal of vegetation; the fossilised remains of this in the shales point to frequent and destructive floods and tides.

The *Portland* formation, formed of successive strata of

greyish limestones and freestones, both deposited in clear seas, follows, and the whole system is capped by the *Purbeckian* stage.

The lower Purbeck rocks, consisting of limestones, have been deposited in shallow, marshy lakes, round which the trees were gradually covered by silt and sand until they died, leaving their stumps standing to testify to the tranquillity with which the destroying agency was at work.

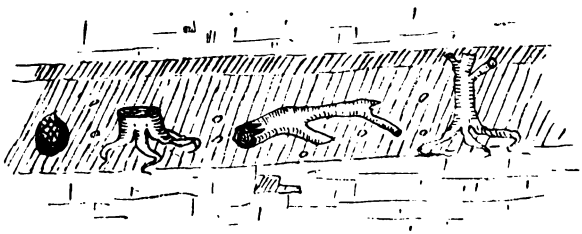


FIG. 85.—Tree Stumps in Purbeck Dirt-bed.

The upper Purbeck beds contain marine shells in endless variety, pointing to the presence of clear seas teeming with life over the now obliterated marshy lakes of the earlier deposits.

These rapid alternations and varied occurrences, some being well displayed in one part of the world and some in others, point to constantly changing climate and geographical distribution of land and sea.

FIG. 86.—Pterodactyl (restored).

In addition to the ichthyosaurus and plesiosaurus, huge animals which were 75 to 100 feet long, 25 to 50 feet in height, and have left footprints a yard square, testify to the enormous size of animal life upon the world in these days. Not only were these huge creatures stalking about on the sands and beaches and swimming in the waters, but pterosaurs, or flying reptiles, coursed through the air.

The earliest known bird occurs in Jurassic strata, and not improbably the woods echoed with song for the first time, as they assuredly did with the humming and chirping of the beetles, flies, grasshoppers, and cockroaches which thronged the trees and grass, and whose presence is known to us by fossilised remains, such as wings, wing-cases, legs, &c. Many fish swarmed in the sea and lakes, a much higher type of crustaceans, of a crayfish-like nature, dwelt upon the rocky bottom of the ocean; while countless species of oysters and clams congregated in quiet, sandy nooks.

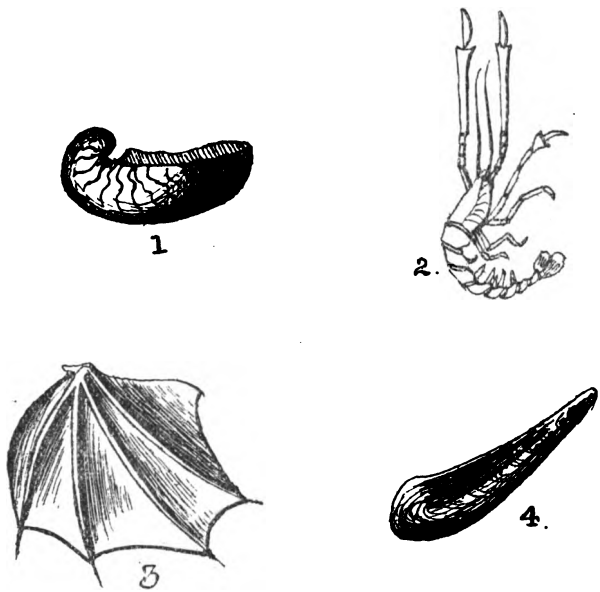


FIG. 87.—Jurassic Fossils.

1. Gryphæa. 2. Megacheinis. 3. Avicula. 4. Modiola.

The plant-life of the world was luxuriant, but still of a great sameness of colour, the bright flowers to which we are accustomed being, as yet, for the ages to come.

Like the Triassic and Permian before it, the Jurassic system has not been greatly disturbed; occasionally vulcanic rocks with dykes of dioryte and other greenstones make their appearance, but for the most part the country where these strata are in evidence retains signs of gentle movement.

Rounded lines of hills and gentle valleys, with valuable soil for agricultural purposes, are the common physical features of this system.

Commercially, Jurassic rocks are of considerable value. From the Bathonian, *Fuller's-earth* (a fine-grained clay of a yellowish colour) is extracted and used for fulling cloth. *Mineral oil* is distilled from the shales of the Kimmeridge stage; *jet, inferior coals,* and *alum* are obtained from the *lias* and *lignite* from the *Bajocian* strata; *ironstone* from the rocks of this system is worked in Yorkshire. The Lias has long been noted for the excellent quality of the hydraulic cement obtained from its limestones, and some of the sandstones (Bath stone and Portland stone) are of excellent quality for building purposes.

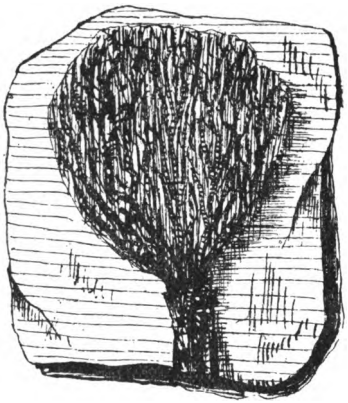


FIG. 88.—Jurassic Crinoid.

Jurassic rocks are widely distributed; they have been identified in Europe, America, India, Australia, New Zealand, and Cape Colony. Although they are not productive of rich mineral deposits, the possibility of finding good oil shales, and perhaps fair coal, should make the system worthy of interest to the prospector.

THE CRETACEOUS SYSTEM.

Named from the Latin *creta* (chalk), this system is chiefly composed of an immense thickness of chalk strata. Like the Jurassic system, it has been divided into a number of formations or stages, generally named after the district where each group is typically developed.

The whole system is evidently of marine origin, and its widespread occurrence testifies to the great changes which must have taken place in the geography of the land; changes in which the physical aspect of the land during Jurassic times

was entirely altered, and the ocean submerged large areas of the earth's surface.

At the bottom of the system is the *Neocomanian* stage, named after Neocomum or Neuchâtel, in Switzerland; it consists of a series of sandy clays and limestones, the former from their colour having been called *greensand.* They were deposited in some huge delta which, in spite of the inpourings of vast quantities of sand, the encroaching sea ultimately covered, as is shown by the upper layers of limestone crowded with marine fossils.

Above this stage comes the *Albian* or *Gault,* consisting of stiff bluish and greenish clays, and pointing to their deposition far from land in still quiet waters; abundant marine fossils in these strata show that the water under which they were spread out was the sea.

The *Cenomanian* (from Cenomanum, an old name of a town in France), or *upper greensand,* as it is still sometimes called, consists of sandy, greenish-coloured deposits, composed of chloritic grains with layers of grey chalk above. The chalk is formed entirely of the broken and crumbled remains of minute marine organisms, and these strata clearly tell us of a muddy and sandy sea which gradually became deeper and clearer until millions of marine creatures were able to live and flourish within its confines. The *Turonian* (from the province of Touraine) stage follows, and consists of many hundred feet of chalk strata, impure and greyish at the bottom, but gradually becoming purer and whiter towards the top.

The dredgings made by the 'Challenger' and other scientific expeditionary ships have thrown considerable light upon the conditions under which these chalk beds must have been deposited. In the warmer latitudes, and over immense areas, the dredge has brought to light the existence on the floor of the ocean of an ooze or mud which is almost entirely made up of decaying portions of the lowly marine *foraminifera*; many of these are identical with existing species, so that we naturally infer that these chalk beds were deposited in some warm, deep sea, and are the consolidated record of conditions exactly like those existing in the tropical and sub-tropical seas of the present day.

The chalk deposits are continued through the two succeeding and closing stages of this system, the *Senonian* (named after Sens, France) and the *Danian* (from Denmark). In these upper-chalk deposits nodules and subangular pieces of dark flint or impure silica are found; good specimens, when broken, show that the silica has been segregated around some organic nucleus in a manner which is at present imperfectly understood. These 'flints,' as they are commonly termed, are found in layers and beds, and also scattered, apparently in no order, throughout the strata. Thus the closing age of the Mesozoic, or middle-life, period would seem to have been one in which the sea was the chief agent at work in arranging the deposits of the time.

FIG. 89.—A Flint Nodule.

That the climate was a warm and genial one we are shown by the remains of both plant and animal life, which have been abundantly preserved in these strata. Various forms of pines, cycads, oaks, palms, junipers, ferns, laurels, figs, magnolias &c. flourished; the foliage began to be less

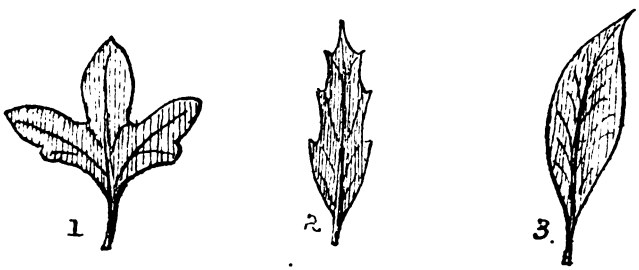


FIG. 90.—Cretaceous Leaves.

1. Sassafras. 2. Oak. 3. Fig.

monotonous and more flowers were to be seen. Reptile life, although still in evidence, was beginning to die out, but a new kind of animal, a toothed bird (odontithornis), made its appearance. Judging from the fossils with which the strata are everywhere crowded, the warm seas must have been teeming with marine life. In addition to the foraminifera alluded to, fossils of echini, or sea-urchins, are common, and

fish of the shark and other tribes have also been preserved in great numbers.

The general outline of country occupied by chalk strata is that of rounded hills and gently sloping valleys. The prevailing white and grey colour of the upper strata and the

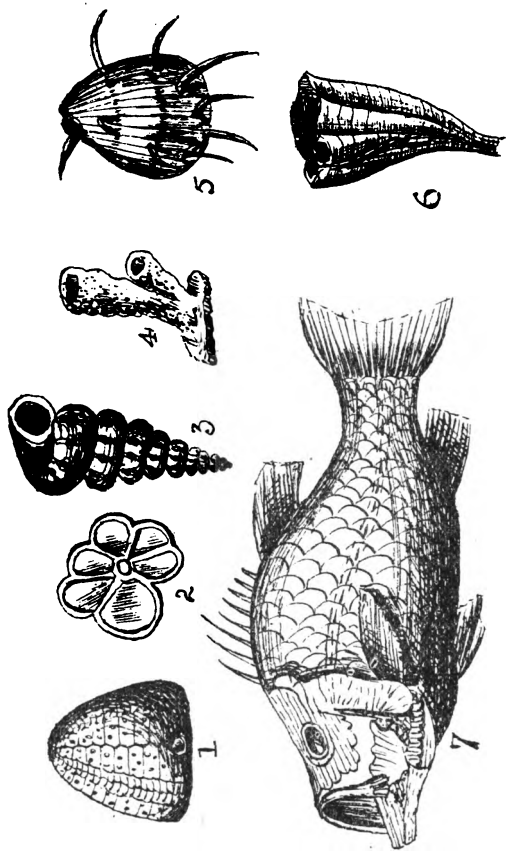


FIG. 91.—Cretaceous Fossils.

1. Echinoconus. 2. Foraminifera. 3. Turrilites. 4. Sponge. 5. Plagiostoma. 6. Hippurites. 7. Beryx Lewesiensis.

peculiar greenish colour of the lower are easy guide-marks for the prospector. Large quantities of basalt and diabase were poured forth in great sheets during the Cretaceous age, while the strata have frequently been upheaved by granyte and various trappean rocks.

Chalk is well distributed over the world. Fossils from

this system have been found in Europe, Palestine, Southern India, in Texas and Alabama, Vancouver Island, in Columbia, on the Andes, and elsewhere in South Africa. 'Cretaceous strata are found north of the Orange River in the Bondelzwarts country.' (A. A. ANDERSON, F.R.G.S.)

FIG. 92.—Radiated Pyrites.

In addition to the chalk, from which lime and whitening are obtained, the flints are used for making porcelain; nodules of phosphate of lime (called 'phosphates') are obtained in the Upper Greensand, and are largely used as manures. Thin coal seams, of good quality, occur, while iron is found, and sometimes worked in the form of *radiated pyrites* (fig. 92).

Where vulcanic rocks have tilted and fissured the strata, ores of copper and lead are not uncommon. Some of the metamorphosed chalks have been converted into beautiful and valuable marbles. Thus, in addition to its scientific

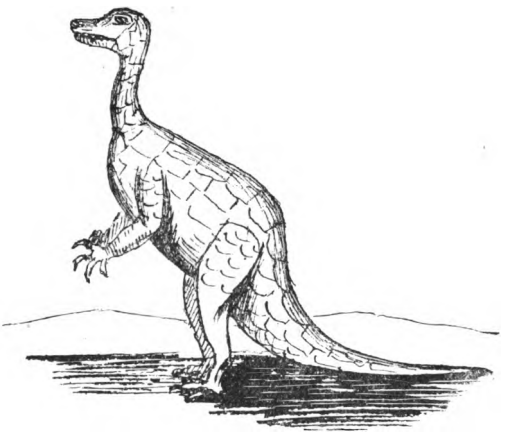


FIG. 93.—Iguanodon (restored about $\frac{1}{100}$).

interest, as containing the records of the close of the Mesozoic period, the Cretaceous system is one which is worthy the attention of prospectors who are looking for commercial products of a mineral but not metallic nature.

TERTIARY, OR CAINOZOIC.

With the uppermost strata of the Cretaceous system, the immense chapter of geological history known as the Mesozoic period, closes. With the advent of the Cainozoic, or recent-life, period we are brought face to face with species of plant and animal life more nearly resembling those that are now existent. The gradations of change throughout the period are very slow, it is true, but they are advances always. A distinct improvement in the species of both flora and fauna is clearly traceable from the lowest formation to the highest, until the one culminates during the Quaternary age in the variegated, many-hued foliage and flowers with which we are acquainted, and the other in God's noblest work—Man.

The huge reptiles and uncouth mammalia which had been swarming on land and in sea during the Mesozoic period gradually disappear. Birds, fish, and animals closely related to forms we see almost daily appear in increasing numbers, while oaks, chestnuts, palms, cacti, willows, elms, poplars, and many other trees with which we are acquainted have early members of their families in the Tertiary woods and forests.

The fossils found in the lower groups of strata indicate that the climate of the earth was, on the whole, genial and warm; but as we ascend the strata we find evidences of a gradual decrease of temperature, until in the Pleistocene age the earth underwent a period of the most intense cold it has probably ever known.

The Tertiary period has been divided into the following systems:—

Eocene, *Oligocene*, *Miocene*, and *Pliocene*. These words are derived from variations of the Greek word, *καινός*, which means *recent*, and they refer to various epochs when the proportion of life related to existing species altered: thus, Eocene means the *dawn of the recent*, a period when a faint resemblance to existing species first appeared; Oligocene means *few recent*; Miocene means *minority recent*, when perhaps 33 per cent. of the species were like existing ones;

Pliocene means *more recent*, and refers to a period when the proportion was over 50 per cent.

Although these systems nearly resemble one another in their fossil relics, and often in their modes of occurrence, vast periods of time must have elapsed during and between the ages in which they were deposited.

The *Eocene* system comprises a series of gravels, sands, and clays, with fresh-water limestones at the bottom and gypsum marls at the top. They bear various local and descriptive names, such as the Bognor and Bagshot beds and the London and Plastic clays.

Some of these beds were deposited in basins shut off from the sea and some in the sea itself. The nummulitic limestone, so called from the crowds of nummulites it contains, was laid down in the sea.

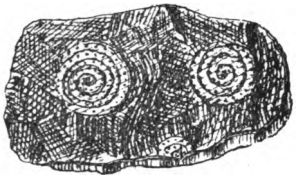


FIG. 94.—Nummulites in Limestone.

The presence of layers of lignite in which remains of terrestrial plants are found with marine fossils points to the presence of land and rivers near to the site of the deposition of these strata.

The *Oligocene* system, consisting of clays, marls, sandstones, and limestones, embraces what are known from local occurrence as the Isle of Wight beds (Hempstead, Bembridge, Osborne, and St. Helens). They have been deposited partly in fresh and partly in salt water. At Bovey Tracey, in Devonshire, in what are known as the Bovey beds, there occur a series of layers of lignite in which fossils of many existing forms of plant and fresh-water life have been recognised.

The commencement of the great vulcanic disturbances, which were at work during the Miocene period which followed, can be clearly noticed in these Oligocene strata. Huge quantities of plastic basalt were outpoured which, spreading over

parts of the land in a great measure, destroyed life and burnt and charred the luxuriant vegetation.

During the *Miocene* age, which followed, vast volcanic eruptions occurred all over the world. The various strata which had been in process of deposition and consolidation

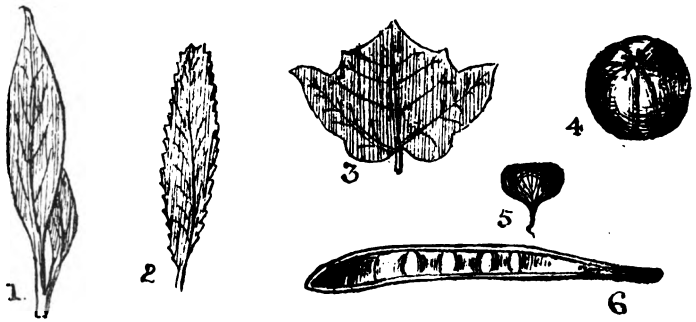


FIG. 95.—Eocene Fossils.

1. Beech. 2. Laurel. 3. Maple. 4. Cucumites. 5. Legumenosites. 6. Mimosites.

during the comparatively quiet ages which had elapsed since the Permian epoch were now ruptured, fissured, and tilted with tremendous energy, until they formed, to a very large extent, the great mountain chains which are still existing. More or less the land and sea assumed the general outline with which modern geography has made us acquainted. The climate of the world, though still warm and genial, was becoming sensibly more temperate.

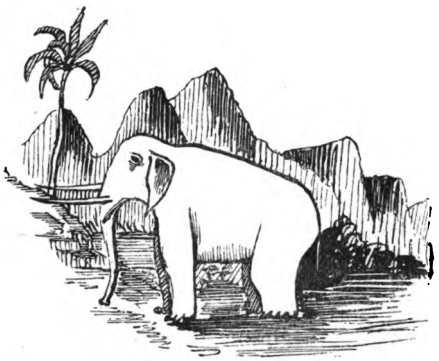


FIG. 96.—Mastodon (restored).

The fossils of plant and animal life which are preserved in these strata are abundant and varied. The leaf-beds of Mull and Antrim present us with fossil types of various forms of vegetable life. Of animal life we learn that snakes, frogs, toads, lizards, beetles, deer, apes, monkeys, bears, wild cats, and

huge animals of the elephant tribe, such as the mastodon, found shelter and food in the marshes and forests and on the hills.

The closing of the Tertiary period was brought about by the volcanic eruptions which took place during the *Pliocene* age. This system includes the Suffolk Crag, in which large numbers of coral remains are found. Upon this lies the Red Crag, an accumulation of shelly sand coloured by iron peroxide. This is succeeded by the Norwich Crag and the Chillesford Beds. All these were deposited in the sea, and probably upon the rocky shore of some turbulent current. In the Norwich Crag, in addition to a large percentage of existing shells, there are quantities of bones, tusks, and teeth of huge mastodon and elephant-like creatures. The last of the Pliocene strata is a series of fossiliferous marine, estuarine, and fresh-water sands and silts.

Fig. 97.—Leaf of Pliocene Walnut.

The great convulsions of nature were now nearly exhausted, and although Vesuvius, Etna, Hecla, Krakatoa, and other great volcanoes have since been in intermittent eruption, volcanic eruption had for the most part done its work and was generally silent. Huge, cold, silent craters all over the world testify to the magnitude of these Tertiary eruptions, eruptions which resulted in the final disposition of sea and land.

For some of the marine fossils of this age see fig. 98.

The description of these Tertiary systems has been purposely curtailed, because they present greater objects of interest to the scientist in search of geological records than to the miner in search of payable minerals. But the great denuding forces which were at work in these and in post-Tertiary and Recent ages have resulted in the formation of beds of gravel, sand, and silt, even as they did in the early Silurian times. These beds are readily accessible to man, and in them he has

found enormous and valuable deposits of gems and minerals. Alluvial gold, the occurrence of which is in part traceable to the result of Tertiary and Quaternary denudation, has been found in vast quantities in the alluvium of existing or ancient

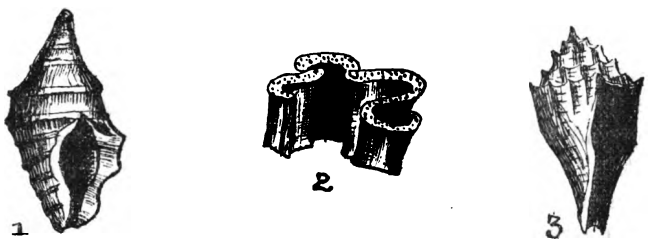


FIG. 98.

1. Purpura. 2. Coral. 3. Volutilithes.

river beds, flats, and lake floors. Platinum, native mercury, stream tin, diamonds, rubies, sapphires, garnets, and other valuable gems and stones also owe their presence in Tertiary strata to the same cause; so that although these formations are not rich in mineral veins they add their quota to the accessible mineral wealth of the globe. Prospectors will do well to examine carefully the floors and banks of the rivers and lakes of this age. From such much of the original wealth

FIG. 99.—Pliocene Mammal.

of Western America and the Australian colonies was obtained, and there can be but little doubt that the treasures of the Tertiary age are not yet all unearthed. In addition to those already mentioned, useful products of these strata are amber, lignite, and phosphates; while much of the stone is valuable for building, milling, and other purposes.

QUATERNARY, OR POST-TERTIARY.

With a description of the final changes which passed over the earth in the *Pleistocene* (most recent) age, the lower of the two systems of this period, we conclude the record of the geological history of the world. In this age there were animals now quite extinct, as well as a large number of existing ones, and the strata merge by almost imperceptible degrees into the *Recent*, which contain no extinct species, and are in process of formation at the present time.

In describing the last period (Pliocene) we alluded to the gradual change of the genial climate which existed at the commencement of the Tertiary age. The presence of shells and animal remains which belong to the frigid arctic zone in the crags of Norfolk and Suffolk, and in other parts of the world, tells us as plainly as if we had ourselves witnessed the change, of the gradual decrease of temperature, of the creeping of the arctic climate from the poles towards the equator.

It has been calculated that 850,000 years ago an eccentricity of the earth's orbit had resulted in the winter being forty-four days longer than now, and the mean temperature of the coldest month to have been −7° F., or 39° of frost, while the hottest month of the short summer had an average temperature of 126° F. Mr. Croll, a celebrated astronomer, has suggested that the Glacial or Pleistocene age may have been during an epoch when, through similar causes to the one mentioned, a greatly prolonged period of intense cold passed over the world. Certain it is, whatever may have been the cause, that the Pleistocene period, immediately preceding the advent of man, was one prolonged polar winter.

At the bottom of the series of Pleistocene strata are polished and grooved rocks, upon which the great ice sheet travelling from the poles has left its trail. Upon these lies the boulder clay, or the bottom moraine (see page 120) of the glacier. In this boulder clay there are some fine layers of clay, sand, and peat, which mark a cessation of the great cold, during which time arctic vegetation, the seeds of which had been transported and preserved in the ice, led a struggling existence.

Above this boulder clay are sands and gravels, said by Professor Geikie[1] 'to be due in some way to the melting of the edges of the ice-sheet,[2] and containing lake shells, terrestrial plants, and animals.'

Perched or erratic blocks, transported by the great ice-

FIG. 100.—Boulder Clay.

sheet, are next in succession, and the series then passes insensibly into recent deposits, leaving traces of the existence of these enormous glaciers in heaps of terminal and lateral moraines (see page 120).

[1] Professor Geikie, LL.D., F.R.S., *Class Book of Geology*, page 468.

[2] Most probably melted during the short hot summers.

The boulder clay, the moraines, and the polished and grooved surfaces which formed the travelling plane for the glaciers are typical features of this epoch. Boulders of rocks of a nature totally foreign to the district where they are found are recognised as identical with rocks existing at great distances from their present position, thus pointing in a most confirmative manner to the power of some great transporting agency. The beds in which they are found exhibit no form of aqueous stratification, and therefore the action of water as the transport agent cannot be upheld. We know of no force that could have carried these blocks so many miles—in many cases hundreds of miles—but ice, and all the evidences go to prove that ice *was* the agent at work.

The fossils that have been preserved to us in these Pleis-

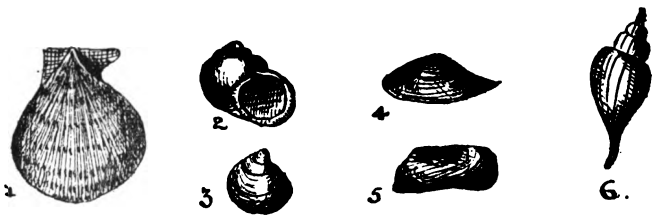


FIG. 101.—Glacial Shells.

1. Pecten. 2. Natica. 3. Astarte. 4. Leda. 5. Saxicava. 6. Trophon.

tocene strata are characteristically arctic, both of flora and fauna.

The remains of the hairy or arctic elephant have been found in Central Europe, while bones and skeletons of reindeer, musk-deer, and the arctic fox have been found far south of their present habitat. Thus both the inorganic and the organic worlds tell us of a period of intense cold, of prolonged winters and shortened summers.

But at last the great cold was removed and a more genial climate again prevailed. Animals which, to escape the cold, had travelled into the tropics, leaving in their bones and skeletons the story of their migrations, returned again to their several habitats. Birds flocked back into the woods and forests, and fish swarmed once more in the seas of the temperate zone. The earth was ready for the advent of man:

in alluvium, cave earth, brick earth, and other recent deposits he has left memorials of his early barbaric state. Some of his tools and instruments are shown on page 200.

To some extent we can read the geological history of the

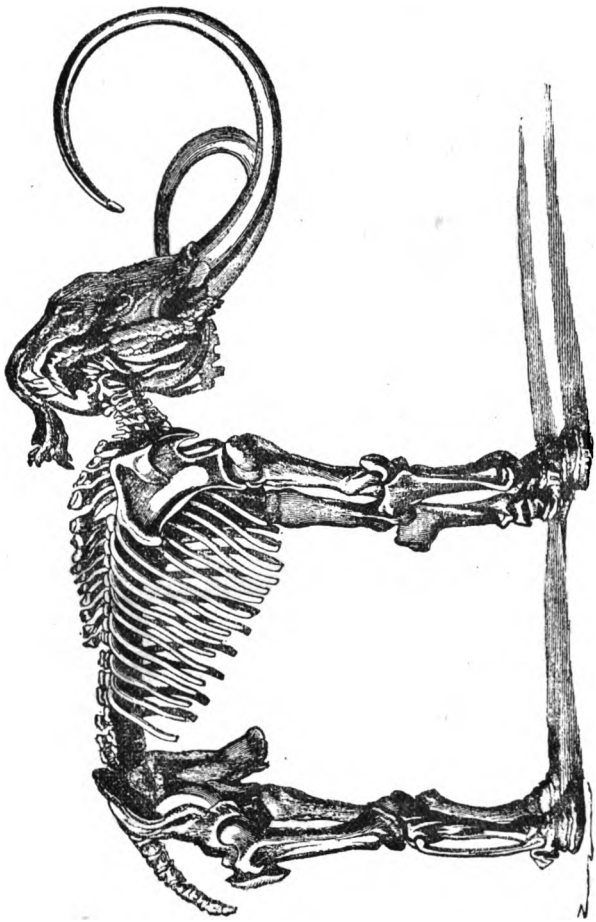


Fig. 102.—Skeleton of the Mammoth, Elephas Primigenius.

earth since man's advent from actual observation and from a study of the changes which he has himself recorded. But a greater book is before us, one in which we must read 'between the lines.' The stratified and unstratified rocks of the earth's crust have a history, too, extending over ages, beside

which the epoch of man's life is but as a moment. The history which they tell us is one fraught with interest and profit, *if* we will but read it aright.

Similar agencies to those which were at work in Silurian times and through the long ages which followed are at work to-day. Fire, water, snow, ice, atmosphere, plants, and animals are ceaselessly engaged in altering and modifying the

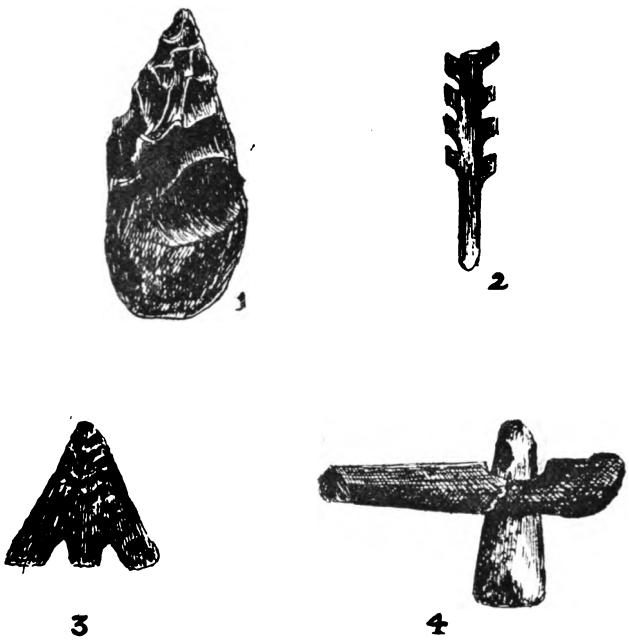


FIG. 103.

1. Flint Implement. 2. Bone Harpoon Head. 3. Flint Arrow-head. 4. Polished Celt, with wooden handle. } All after Prof. Geikie.

earth's surface and its outline. We can see in the processes of nature to-day the counterpart of those in days gone by, and we can but believe that, as they have been, so they will be, for man's ultimate benefit.

The limits of this book are such that much of this subject has been curtailed or obliterated. What has been written has been considered as necessary of attainment by all those who

would intelligently search after the buried treasures of nature. There is nothing to be learnt or gained without labour, but a diligent and an observant student will soon learn that although these treasures are, in many cases, buried, the rocks of the earth are but guide-posts to show him where they lie.

SECTION V

ASSAYING AND BLOWPIPE ANALYSIS

CHAPTER I

Assay Apparatus and Assaying

Assaying is the art of ascertaining the constituents of which a substance is composed, and the proportion of those constituents by means of dry reagents and fire. The object is, usually, to ascertain the amount of a metal or metals in an ore. In some instances, as in estimating copper, it is more convenient to employ *wet* methods, and these are usually spoken of as *wet assays*, although they belong essentially to the processes employed in chemical analysis.

The following are the minerals commonly estimated by assaying: Gold, silver, copper, lead, tin, zinc, iron, cobalt, nickel, antimony, bismuth, and platinum.

There will be given here methods of estimating those metals only with which the prospector is likely to have to deal, and these will be treated of in as simple a manner as possible. To make accurate assays, considerable experience and manipulative skill are required, and it will generally be found desirable to employ a professional man for such work, it being sufficient in most cases for the prospector to determine the metals in any ore by means of the blowpipe, or, if gold is sought, by 'panning.'

Apparatus used in Assaying.

The following list of apparatus will be found sufficient for ordinary work on a variety of metalliferous minerals, but where the constant estimation of one particular metal is the work to be performed, a special outfit is desirable:—

List of Apparatus.

Portable assay furnace, with fittings for fusions.
Portable cupellation furnace, with fittings for fusions.
6 dozen nests *Hessian* crucibles.
12 assay muffles for cupellation furnace.
6 dozen French crucibles, assorted.
1 dozen plumbago crucibles, assorted.
6 dozen scorifiers.
6 dozen roasting dishes.
6 dozen covers, potstands, &c., *assorted.*
Assay scales, with three sets of weights (*grain, troy,* and *avoir.*).
No. 8 assay balance (Oertling).
2 iron mortars and pestles (*large* and *small*).
6 small assorted ingot moulds.
2 sets cupel moulds.
4 pairs tongs (*various*).
Anvil and hammer.
2 chisels.
2 hammers.
Blowpipe.
Mallet.
3 files.
2 pairs common tongs.
2 pairs pincers.
1 pair scissors.
Poker, shovel, and rake.
2 ladles.
Magnet.
Magnifying glass (folding).
Drill brush.
2 pallet knives.
1 set three sieves.
3 copper bowls.
Copper shovel.
Copper shoot.
12 assay flasks.
12 assorted flasks.

6 *Berlin* dishes.
3 graduated measures.
Leather gloves and apron.
Assorted filters.
6 nests test-tubes.
Sand bath, retort stand, and Bunsen burner or spirit lamp.
6 dozen *French* cupels, No. 3.
6 dozen *French* cupels, No. 4.

Dry Reagents required for Assaying.

Argol (or cream of tartar).
Black flux.
Bicarbonate of soda.
Borax.
Carbonate of ammonia.
Carbonate of potash (or soda).
Common salt.
Cyanide of potash.
Flour.
Iron (*nails* and *wire*).
Lead (*sheet* and *granulated*).
Litharge.
Nitre.
Silica.
Silver (pure).
Copper (pure).
Sulphur.
Wood charcoal.
Bone ash (for making cupels).

The following liquid reagents will also be found necessary or useful:—

Distilled water.
Nitric acid.
Alcohol.
Bichromate of potash.
Bromine.
Hydrochloric acid.

Sulphuric acid.
Nitric acid.
Metallic mercury.
Sulphuretted hydrogen water.
Ammonia water.
Caustic soda (solution).

General Preparation of an Ore for Assay.

When specimens are taken for assay, the greatest care should be exercised to obtain a fair average sample. It too often happens that rich specimens are selected, which, giving high results that are not the least use as guides to the average value of the ore, are nevertheless employed for the purpose of disposing of or floating the property. Unless care is taken in obtaining average ore for assay, the result is useless and misleading.

To *sample* ore, a heap of several tons of average quality should be taken. In this two trenches are made across the heap at right angles to one another. The ore thus obtained must be broken up to about the size of walnuts, placed in a heap and subdivided as before. This is crushed still finer, thoroughly mixed, and halved, the process being repeated until about 1 lb. of ore is resultant. This portion is crushed fine in a mortar, and the whole passed through a sixty or eighty mesh sieve, care being taken not to lose any flattened particles of metal which do not pass through the mesh. These latter must be carefully broken up until they are fine enough to pass through, or their weight taken and allowed for afterwards. The prospector or miner should use his judgment in the sampling of an ore, according to circumstances, always remembering that the object is to obtain a *fair average* sample. When the ore is to be taken directly from a lode, it must be obtained from a number of places as far apart as possible, and in each case, where practicable, from the hanging to the foot wall, *right across the lode.*

Great care is necessary in numbering samples so as to avoid confusion and mistakes afterwards. A convenient way to distinguish them is to place each different sample in a canvas bag with a string and tally attached. The tallies are

numbered consecutively, and a note is made *at the time* in a pocket-book as to the number and contents of each bag. If such bags are not obtainable, strong paper can be used to wrap the ore in, each packet being carefully numbered, as mentioned above.

Assay of Gold and Silver Ores.

There are two methods employed in the fire assay of gold and silver ores :—

1. Scorification process.
2. Crucible process.

The process employed should depend upon the nature of the ore. As a rule, the first method is more suitable for silver ores and rich gold ores, and the second for poor gold ore. The chief advantage of the latter method is that larger quantities can be operated upon than in the former one.

1. *Scorification process.*—The chief reagents used are granulated lead and powdered borax glass. Silica, iron, and sodium-bicarbonate are sometimes employed.

Under the action of heat the lead fuses and forms an alloy with the gold or silver present in the ore, which sinks to the bottom of the scorifier, while the borax or other flux unites with the gangue, which floats upon the surface of the molten alloy.

The various processes should be conducted in the following order :—

1. Preparation of charge.
2. Scorification.
3. Cupellation.
4. Weighing bead (an alloy of gold and silver).
5. Inquartation (when necessary).
6. Parting.
7. Weighing residue of fine gold.
8. Calculations.

Weigh out—

Powdered ore	50 grains.
Granulated lead	500 ,,
Borax	5 ,,

Mix the ore with half the granulated lead and cover the mixture with the remainder of the granulated lead and borax. When the temperature of the muffle is right (pale red heat), place the scorifier, which has been previously heated, well into the muffle. After a lapse of three or four minutes, when the charge will be melted, partly open the muffle door to admit air, which acts as an oxidising agent. When the alloy is thoroughly melted it is well to add a few grains of powdered anthracite wrapped in tissue paper, as it has a cleansing action on the slag. When the molten lead is entirely covered with slag the heat is increased in order to thoroughly liquefy the slag; then withdraw the scorifier, and pour the contents into an iron mould previously warmed. When cold the button of lead is detached from the slag and hammered into the shape of a cube. This lead contains the gold and silver which was in the ore taken, and is now ready for cupellation.

The proportion of granulated lead used must be varied according to the nature of the ore, the quantity being *increased* when much sulphur, arsenic, or antimony is present. Lead used in assaying should be cupelled before using, as it invariably contains some silver. The amount of silver in the lead thus ascertained is afterwards allowed for in all calculations.

A cupel is selected, a little heavier than the lead to be cupelled, and placed in the muffle, which must be at the proper heat, *neither too hot nor too cold, but better the former than the latter.* The exact temperature—an intense heat—can only be learned by practice. When the cupel has reached the temperature of the muffle, the lead button is placed in it and the muffle closed. In about a minute the lead will be completely melted, and the door is slightly opened to admit a current of air. If the temperature has been correct the cupel will be red and the molten metal very luminous. The button gradually diminishes, and at last a bright shining speck of silver, or an alloy of gold and silver, alone remains. The sudden brightening which takes place when the last trace of lead disappears is known as *flashing*, and indicates that the process is finished. The cupel should then be slowly cooled, especially if the bead be large. When *quite* cold the

bead is taken from the cupel, cleaned with a small brush, and carefully weighed.

The gold and silver have now to be separated by dissolving out the latter. This process is known as *parting*. The bead is hammered out flat, bent into a coil, and transferred to a parting flask, the bulb of which is three-quarters filled with *dilute nitric acid* (1 part acid and 3 parts water) and allowed to boil for fifteen minutes. Then pour off the acid, wash with distilled water, add stronger acid (1 part acid to 1 part water), and boil for twenty minutes. Pour off acid, wash residue with distilled water, fill up flask completely, and invert in small crucible. The gold residue will thus fall into the crucible, and the flask can be rapidly withdrawn. Pour off water from gold in crucible; dry, ignite, and weigh. If no residue is left in this process, then gold is absent and only silver may be present.

When a bead of gold and silver contains less than three parts of silver to one part of gold, all the silver cannot be dissolved out by nitric acid. In such a case silver must be added to the bead before 'parting.' This process is known as *inquartation*. Weigh out some thin and pure silver foil equal to about twice the weight of the bead, roll up bead and silver foil in from 10 to 20 grains of lead foil, and cupel as before. Hammer out bead, roll into coil, and part as above described. Wash, dry, ignite, and weigh gold residue.

The manner of calculation depends upon the system of weights used. The simplest calculations are obtained by using the conventional assay ton weights in weighing out the ore. One assay ton is equal to about 450 grains, or 29,166 milligrammes. If one assay ton of ore gives a residue of gold weighing 2 milligrammes, then a ton of ore contains 2 oz. of the precious metal; so that the weight in milligrammes of the gold residue gives directly the number of ounces of gold per ton of ore. If the above system is not employed, it is usual to employ troy weights for the *precious* metals and avoirdupois for the *common* ones. The former are expressed in *oz.*, *dwt.*, and *gr. per ton of ore*, while in the latter case the percentage of metal is stated.

2. *Crucible process.*—This method is not so easy to conduct

satisfactorily as the preceding. A knowledge of the nature and composition of the ore, as well as the action of the various reagents employed, is essential, and the student is referred to some good manual of assaying (see Appendix) for full information on this subject.

For an ore chiefly composed of siliceous material take—

Ore	500	grains.
Carbonate of soda . .	600	,,
Red lead . . .	500	,,
Charcoal . . .	25	,,

If iron or other metallic bases are present, part of the carbonate should be replaced by borax, the amount being increased in proportion to the quantity of metallic bases present.

The ore and reagents must be thoroughly mixed and placed in crucible in a hot fire. In about twenty minutes the mass will be thoroughly fused and quiet. Withdraw the crucible from fire and pour contents into mould. Allow to cool, detach slag from button, hammer into cube, and proceed to cupel &c. as in scorification process.

The following proportions of ore and reagents have been employed by the author with excellent results in assaying the auriferous conglomerate of the Witwatersrandt Gold Fields, South Africa :—

Ore	1,000	grains.
Sodic carbonate . .	1,000	,,
Red lead . . .	500	,,
Charcoal . . .	14	,,
Borax	200	,,

For an argentiferous or auriferous copper ore weigh out 100 grains; and if sulphur is present, calcine in crucible till *sweet* (till no odour of sulphur can be observed).

Powder calcined ore and mix with—

Red lead . . .	1,000	grains.
Charcoal . . .	40	,,
Sodic carbonate . .	200	,,
Borax	300	,,

Well mix and place in crucible with half the borax on top and fuse as before. Detach slag and any regulus present.

Powder slag and mix with—

Red lead . . .	300 grains.
Charcoal . . .	25 ,,
Sodic carbonate . .	20 ,,

Mix and fuse as before. Detach slag and cupel both buttons. The regulus (if any) should be rolled up in paper and placed on the cupel along with first button. The beads obtained from the cupels must now be parted, &c.; the sum of the weights of the gold residues will then give the amount of precious metal in the ore taken.

It is sometimes desirable to ascertain roughly the amount of free gold in an ore by a method approximating to the conditions under which gold is amalgamated in an ordinary stamp mill.

A simple method of conducting this process is to powder finely about 2 lb. of ore and then to 'pan off' (Section VI., page 241) the greater part of the lighter material. The remainder is carefully washed into a mortar and a few drops of mercury added. The whole is then well grounded with a pestle until all the free gold has been taken up by the mercury. When this is accomplished the whole is transferred to the pan, and the remaining light material carefully washed away. The pan with the amalgam is placed over the fire to dry, any remaining particles of quartz &c. being afterwards carefully blown away; the amalgam is now heated in a small porcelain crucible, the mercury by this means being driven off and a residue of gold left, which, when cold, is weighed carefully.

Assay of Mercury Ore (Cinnabar).

From 50 to 100 grains of finely powdered ore are taken and mixed with about twice their weight of quicklime. A combustion tube about 18 inches long, closed at one end, is filled, as shown in fig. 104, the mixture of ore and quicklime occupying the middle part. When the tube is filled the open end must be drawn out to a point and bent, as shown. Place

the tube in a charcoal furnace with the open point just dipping below the surface of cold water contained in a convenient vessel. Now pack lighted charcoal round the tube, taking care not to increase the temperature too rapidly. The part of the tube containing the sodium bicarbonate must be heated last, as it is by the gases given off through its decomposition

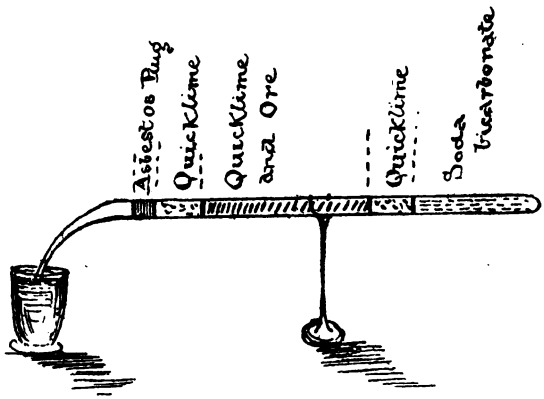


FIG. 104.

that the last traces of mercury are driven from the tube into the water. The process lasts about thirty minutes. When no more mercury comes away, remove the tube, taking care to shake any globules of mercury clinging to the cool part of the tube into the water. Pour off the water from the mercury globule, dry, and weigh in small porcelain crucible.

ASSAY OF LEAD ORES.

The common ore of lead is galena (lead sulphide). For a fairly pure sample take—

Powdered ore	400 grains
Carbonate of soda	400 ,,
Argol	30 ,,

When the ore is impure it is better to take 350 grains of carbonate of soda and 50 grains borax, the latter being placed on the top. Place the mixture in crucible with one-fifth of the carbonate of soda on top; push three or four large iron nails

into the mixture, place crucible in furnace, and cover. Pack round the crucible small pieces of coke and heat for twenty-five minutes. When effervescence ceases remove the iron nails and pour contents into a warm iron mould. When cold detach slag and clean lead button with warm water and a small brush. Hammer into the form of a cube and weigh. An iron crucible may be used in place of the earthen one, in which case the iron nails are unnecessary.

Galena almost always contains *some* silver, which it is often desirable to estimate. In such a case, after the lead button is weighed, it is cupelled. If the lead button be large it can be cut into two or more pieces, each piece being cupelled separately. The bead (or beads) of silver so obtained are then weighed.

Assay of Copper Ores.

The fusion assay of copper ores is somewhat complicated, and requires much practice to obtain reliable results. It is therefore usual to estimate the percentage of copper in an ore by the wet process.

To make standard solution.—Take about 2,000 grains of potassic cyanide and dissolve in four pints of water. Weigh out accurately about 6 grains of electrotype copper and dissolve it in strong dilute nitric acid (one part acid one part water). When the copper is completely dissolved add a little water and heat, to expel fumes. Dilute and transfer to flask, which should be half filled with water. Add ammonia in slight excess, or until the liquid is of a blue colour throughout. Allow to stand till *cold*, then from a graduated burette run in the potassic cyanide solution until the blue colour has disappeared and a faint violet tint is apparent; then read off the number of cubic centimetres of solution used. Now, supposing that the weight of copper taken was 6 grains, and that the number of cubic centimetres of potassic cyanide required to decolourise the solution was 60; then a cubic centimetre of the cyanide solution will decolourise a solution containing one-tenth of a grain of copper.

If the ore to be estimated is a carbonate or an oxide, weigh out 15 grains finely powdered and place in flask. Add

hydrochloric acid, heat for thirty minutes, add a few drops of nitric acid, heat for ten minutes, dilute and transfer to larger flask, add water until half full and then ammonia in slight excess, and when *cold* proceed as described above. Supposing 64 c.c. of potassic cyanide are required to decolourise the solution; then the percentage of copper in the ore

$$=\frac{64 \times 100 \times 1}{15 \times 10}=42{\cdot}6.$$

For copper ores containing sulphur, proceed as follows:—Weigh out 20 grains of powdered ore and place in flask; add sufficient sulphuric acid to moisten and then nitric acid until about ¼ in. deep; heat for one hour, add a little water to expel fumes, dilute, transfer to large flask and proceed as before.

If the weighed ore is first calcined until 'sweet,' the process employed for oxides may be used.

The presence in the ore of silver, iron, arsenic, zinc, or nickel renders this process inaccurate, and in such a case it is necessary to remove these metals by chemical processes before reliable results can be obtained.

A simple and fairly accurate way of estimating copper in an ore is to weigh out a quantity of finely powdered ore if sulphur is present, roasting till 'sweet;' then dissolve in hydrochloric acid with a few drops of nitric acid.

Evaporate to dryness, dissolve in water, and pour the solution into a basin. Insert a well-polished sheet of iron and allow to stand for an hour or more. The copper will be deposited on the surface of the iron in the form of powder, and may be rubbed off with a brush and weighed.

Assay of Tin Ore.

Take—

Ore	100 grains.
Potassic cyanide	600 ,,

Well mix, place in crucible and heat strongly in furnace for twenty minutes; withdraw from fire, allow to cool, break crucible, collect beads of tin, and weigh. If the ore contains

sulphides it should be calcined before being mixed with the potassic cyanide.

Another method is to take—

Ore	500 grains.
Powdered anthracite . . .	100 „

Mix well and fuse in a crucible at an intense heat for twenty minutes. Then pour the contents of crucible into mould; allow to cool, detach slag, carefully examining it for beads of tin, and weigh the button and beads.

Assay of Iron Ores.

The prospector is not likely to want to estimate the percentage of iron in an ore. For iron ores to be of commercial value it is necessary that they should exist in large quantities, fairly pure, with cheap fuel and other facilities near at hand. The presence of certain impurities in comparatively small quantities often seriously affects their value, and the estimation of these and the iron present is a process which requires both chemical knowledge and skill; it is therefore not thought desirable to give the methods here.

CHAPTER II

Blowpipe Analysis

By the aid of the blowpipe a few reagents, and some simple apparatus, the composition of a mineral—more especially the metallic ones—can be readily determined, and its nature and value to a great extent ascertained. The results usually sought are qualitative, although some metals can be determined quantitatively, but to do so is an operation of considerable delicacy, and requires skill and practice to perform successfully.

Cases containing a complete blowpipe outfit can be purchased from any good mineralogist, but it will be found more convenient for work in the field to take only those things which are absolutely necessary, and to have these carefully wrapped up in a piece of wash-leather or strong cloth.

The following list of apparatus and reagents will be found sufficient for ordinary work:—

Blowpipe.
Candle or small lamp.
Four pieces fine platinum wire 3 in. long.
Pair of platinum-tipped forceps.
Piece of charcoal, or
Charcoal pastilles with porcelain support.
Closed and open glass tubes.
Small test-tubes.
Agate mortar and pestle.
Diamond mortar (*of cast steel*).
Small hammer.
File.
Pocket-knife.

Magnet.
Lens.
A few watch glasses.
Borax.
Carbonate of soda.
Microcosmic salt.
Sulphuric acid.
Nitric acid.
Hydrochloric acid.
Solution of cobalt nitrate.

The most convenient form of blowpipe is that shown in fig. 105. The chamber, A, serves as a reservoir for any condensed moisture, and prevents it being projected into the flame. The form and size of the aperture in the jet are important; the opening should be perfectly round without any projecting portions. If it is not satisfactory it should be

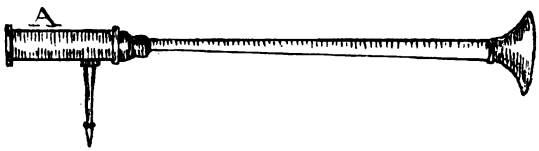


Fig. 105.—Blowpipe.

hammered up slightly and then enlarged by inserting a good-sized sewing needle. Platinum jets, instead of the usual ones of brass, when properly made are to be preferred. Those of platinum foil are too fragile and liable to damage, but when solid they are very durable, and will last a lifetime. The mouthpiece may be either trumpet-shaped as shown, or tubular. In either case it should be made of bone or ivory. The former shape is less fatiguing to the muscles of the lips and cheeks, but the latter shape has the advantage in the fact that the blowpipe can be held and steadied somewhat by the teeth. The various pieces of the blowpipe should be detachable for convenience in carriage.

The source of heat employed depends upon the circumstances under which the prospector is placed. Ordinary illuminating gas is best when it can be obtained. It should be

burned through a slit about $\frac{1}{8}$ in. wide by $\frac{3}{4}$ in. long. Such a burner can be readily made by flattening an ordinary piece of iron tubing. The top should be filed obliquely so as to present a gentle slope with the horizontal, it being often convenient to divert the blowpipe flame downwards. It is not, however, to be expected that the prospector will often have the use of gas, and in its absence an oil lamp, or a stearine, paraffin, or even common tallow candle can be made to answer very well. A lamp, burning *olive* or *rape-seed* oil, made of metal with a cap to screw down over the wick is to be recommended, as it is very convenient to carry about.

The platinum wire is used for supporting beads of borax &c. in the blowpipe flame for testing the flame colouration of minerals in the state of powder.

Platinum-tipped forceps are useful for holding fragments of minerals in the blowpipe flame to test their fusibility and flame colouration. The points should open by pressure so that the splinter is held by the natural spring of the forceps. Metallic-looking substances should never be held in the forceps, owing to the danger of the metal present forming a fusible alloy with the points.

Charcoal is used as a support for the assay in obtaining sublimates &c. Specially prepared rectangular blocks are best, and will last a long time; but any well-burned charcoal that does not crackle or fissure in the flame will answer the purpose.

Closed and open glass tubes are used for studying the reactions which minerals undergo when heated in the absence and also in the presence of air.

The dry reagents are most conveniently carried in wooden boxes, the liquid ones in small stoppered bottles which fit into wooden boxes having lids that screw down upon the stopper. By these means loss through leakage or evaporation is lessened.

The Blowpipe Flame.

One of the first and most important things to be learnt in blowpipe analysis is the proper manipulation of the flame. It is often necessary to maintain a steady blast of air for

several minutes, and to do this requires some practice; but the method once learnt becomes quite easy and natural. The steady and constant stream of air needed is obtained by the action of the muscles of the cheeks. The student should first practise keeping the cheeks constantly distended, exhaling by the lips and inhaling through the nose.

The mouthpiece of the blowpipe should then be inserted between the lips, and the same thing repeated. The air will gradually escape; as it does so the cheeks have a tendency to fall, but are kept distended, *without a check in the continuous flow of air*, while the natural action of the lungs continues through the nose. With a little patience and practice he will soon be able to maintain a steady and gentle blast for several minutes at a time.

To obtain an Oxidising Flame (O.F.).

Place the nozzle of the blowpipe some distance into the flame and blow strongly; a pale blue flame surrounded by a nearly colourless envelope should result. This is the oxidising flame (O.F.) (see fig. 106).

Fig. 106.

The most powerful oxidising action takes place at the point *a* of the colourless envelope. The point *b* of the blue portion gives the most intense heat, and it is at this point that minerals should be held when testing their fusibility.

To obtain a Reducing Flame (R.F.).

Hold the nozzle of the blowpipe just outside the flame and blow gently. A luminous blue cone, the *reducing flame* (R.F.) (fig. 107), is obtained. The most powerful reducing

action takes place at the extremity *c* of the luminous portion. The flame should envelope the assay so as to exclude the air.

The learner may test the efficiency of the O.F. and R.F. he is able to produce by making a small loop about ⅛ inch

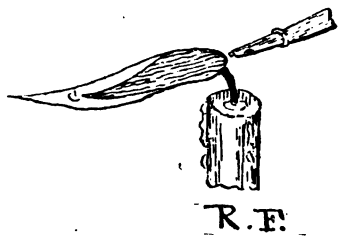


FIG. 107.

diameter on the end of the platinum wire, and then forming upon it a borax bead. To do this a small quantity of borax is shaken from the box and the end of the wire dipped into it *while hot*; that which adheres is then fused into a *clear globule*. This globule while hot may be dipped into oxide of manganese, a minute quantity being taken up at first, and the amount gradually increased. A red violet bead is produced in the O.F., which becomes colourless in the R.F.

The following is the order in which the various tests, described in succeeding pages, should be conducted:—

1. Heat in *closed tube* } Observe gas evolved, sublimate, &c.
2. „ *open tube* }

3. Hold a splinter in the hottest part of the flame, and note the *fusibility* and *flame colouration*, if any. The latter is often only apparent after the splinter has been dipped in strong hydrochloric or sulphuric acid.

4. Heat on *charcoal* in O.F. Note intumescence or fusion and any incrustation produced.

5. Moisten any white incrustation or residue with *nitrate of cobalt*, reheating strongly in O.F. and noting any colour produced.

6. Heat on *charcoal* in R.F. Note nature of product, its magnetic properties, any beads of metal procurable on breaking up residue, &c. Encrustations are sometimes formed, and should be tested as in 5.

7. If no result has been obtained in 6, mix with a little *carbonate of soda*; heat in R.F. and re-examine.

8. *Test for sulphur* with silver coin (see page 36).

9. Observe the colouration produced in *borax bead.*

10. Observe the colouration produced in *microcosmic salt bead*, and any undissolved silica if present.

11. Test for manganese, which may have been masked in previous tests, by means of *carbonate of soda bead.* This test is exceedingly delicate, and often reveals the presence of minute quantities which are not essential to the mineral under examination, but only accidental impurities.

12. Note *solubility in acid*, with or without effervescence; also whether effervescence, not previously seen, takes place on heating; also if silica (gelatinous or powdery) separates out.

It is seldom necessary to go through the whole of the above tests to identify any mineral, although for the beginner it would be well to do so. After some practice he will usually know from the appearance, specific gravity &c. of the mineral what tests to apply.

A note of each test and the conclusions to be drawn from it should be made in a book kept for the purpose, each page being divided into thirteen columns. In the thirteenth column the conclusions arrived at from the whole series of experiments should be stated.

Reactions in Glass Tube.

I. *With closed tube.*—Hard glass tubes are taken about ¼ inch diameter and 6 inches long. By heating in the centre and slowly drawing apart two closed tubes are made. Dry a tube thoroughly by warming; place a small quantity of the substance under examination in the bottom, taking care that no particles remain on the sides; heat at first gently, and afterwards strongly.

The following reactions may be taken as examples of the changes to be looked for:—

a. Change of colour.—Chalybite becomes black, and may be attracted by the magnet.

b. Decrepitation.—Chalybite, pyromorphite.

c. Evolution of gas.

(1) *Oxygen.*—Mercuric oxide, manganic oxide. Test by introducing a glowing match when the tube is well heated. If oxygen is present the match immediately bursts into flame.

(2) *Sulphurous acid* and other gases recognisable by their smell. These may be better observed with the open tube.

(3) *Fluorine.*—When compounds of fluorine are strongly heated in the closed tube, in the absence of moisture, and a moistened glass rod inserted, a gelatinous deposit is sometimes formed upon it. Experiment with cryolite.

d. Sublimate formed.

Colour.	Composition.	Example.
1. Yellow, orange when hot	Sulphur	Iron pyrites.
2. Yellow-red, dark brown-red when hot	Arsenous sulphide	Orpiment.
3. Brown-red, black when hot	Antimonous oxydisulphide	Antimonous sulphide.
4. Grey metallic, garlic odour	Arsenic	Smaltite.
5. Grey, metallic, in globules	Mercury	Mercuric oxide.
6. Yellow to green	Cupric chloride	Cupric chloride.
7. Black, red on rubbing	Mercuric sulphide	Cinnabar.

8. Water.—The tube should be quite dry before the experiment. Distinguish between hematite and limonite.

The globules of mercury are rendered more apparent by scraping the inside of the tube with a match or chip of wood and then shaking them out on to a piece of paper.

The end of the tube containing the black sublimate from cinnabar should be broken off and some of the sublimate rubbed on paper.

II. *With open tube.*—The substance is placed about ¾ inch from the lower end of the tube, and the tube inclined so as to allow a free current of air to pass during heating. The inclination should be varied according to the substance driven off. Where the results are different from those obtained in the closed tube, this is due to the oxidation of the substance, or of the sublimate as it is evolved. Hence sulphides may be deposited in the closed, and oxides in the open tube.

The following reactions may be taken as illustrations of the changes to be looked for :—

a. Change of colour.—Cuprite is converted into black cupric oxide.

b. Evolution of gas.—(1) *Sulphurous acid* and gases recognisable with their smell. Experiment with iron pyrites.

(2) *Fluorine.*—Where fluorine is suspected the substance should be ground up with microcosmic salt that has been previously fused on charcoal. Heat this mixture in the open tube, *directing the blowpipe flame inside the tube.* Hydrofluoric acid—or, often, silicic fluoride—will be given off; the former will etch and dull the glass, as may be seen on washing the tube out with water. When the glass is too soft to withstand the high temperature required, the substance may be laid in a short tube formed from platinum foil, inserted as a prolongation of the glass one. Experiment with fluorspar and cryolite.

c. Sublimate formed.

Colour.	Composition.	Example.
1. White, crystalline and volatile	Arsenous anhydride	Smaltite.
2. White, near the substance; yellowish when hot	Antimony oxides .	Antimonous sulphide.
3. White, fusible, not volatile; forms on under side of tube	Plumbic sulphate .	Galena.
4. Yellowish-white to white; dark-brown to yellow when hot	Bismuthous oxide .	Bismuthous sulphide.
5. White, thin, crystalline; yellowish when hot	Molybdic anhydride	Molybdous oxide.

Flame Colourations.

Take up on a moistened loop of the platinum wire a little of the powdered substance; hold this in the almost invisible oxidising flame, and note any colouration imparted to the flame.

Add a few drops of hydrochloric acid to the substance, and note any development or intensification of the colouration. Many minerals give no result until thus treated.

Where the foregoing tests give no colouration, and in all cases where phosphorus is looked for, moisten the substance with sulphuric acid and heat again.

The flame colouration is usually observed while the fusibility of a splinter of the mineral is being tested. Thorough

familiarity with the colours and shades of colour given by different substances is necessary, as the indications are often slight and transient.

The following reactions may be taken as examples :—

	Colour of Flame.	Indication.	Example.
Red	Purple red	Lithium	Lithic chloride.
	Red	Strontium	Strontic chloride.
	Duller or yellowish red	Calcium	Calcic chloride.
Green	Yellow green	Barium	Baric chloride.
	,,	Molybdenum	Molybdic anhydride.
	Emerald green	Copper	Cupric oxide.
	Blue green	Phosphorus	Microcosmic salt.
	Grass green	Boron	Borax.
Blue	Light blue	Arsenic	Arsenous anhydride.
	Green blue	Antimony	Antimonous oxide.
	Azure blue	Chloride of copper	Cupric chloride.
	,,	Selenium	Selenium.
	,,	Lead	Plumbic oxide.
Yellow		Sodium	Sodic chloride.
Violet		Potassium	Potassic chloride.

Special Reactions.

1. Potassium and sodium frequently occur together, when the former gives no visible reaction, owing to the strength of the sodium flame. In many cases the potassium flame can be made visible by the use of plates of blue glass. Choose a thickness of blue glass sufficient to render a strong sodium flame invisible; then mix potassic and sodic chlorides until the violet potassium flame cannot be detected by the eye. Observe such a flame through the blue glass chosen; a portion will now be visible, which will be due to the presence of the potassium. This test requires some careful practice before it can be applied to the examination of minerals.

2. Chlorine may often be detected by grinding up the substance with a little cupric oxide, which alone gives a pale green flame; when the mixture is held in the flame the blue due to cupric chloride is seen around the substance. Experiment with baric chloride.

Reactions on Charcoal.

A little of the powdered substance, or a small fragment, is placed in a hollow cut with a knife point in the charcoal, and the blowpipe flame is directed upon it. A sufficient area of charcoal should lie beyond the hollow, so as to provide a cooler surface on which any sublimate may be deposited. If the substance decrepitates or easily blows away, it may be mixed with a little water and gently brought to a good heat. The surface of the charcoal used must be thoroughly scraped away after each operation.

The ash given by the charcoal alone should be examined to avoid it being confused with any of the white sublimates.

1. *With oxidising flame.*

(*a*) *Incrustations.*—Observe the following incrustations and the comparative ease of their production :—

	Colour.	Indication.	Example.
1.	White, garlic odour	Arsenic	Arsenous anhydride.
2.	„ nearer substance	Antimony	Antimonous sulphide.
3.	„ yellow when hot	Zinc	Zincic sulphate.
4.	„ „ „	Tin	Stannic oxide.
5.	White, yellow when hot; blue when touched with R.F.; volatile, but leaving a copper red stain	Molybdenum	Molybdic anhydride.
6.	Yellowish white	Bismuth	Bismuthous sulphide.
7.	Yellow	Lead	Lead.
8.	Brown	Cadmium	Cadmic hydrate.
9.	Brown red (difficult)	Silver	Argentic nitrate
10.	Reddish to yellow brown	Chloride of copper	Cupric chloride.

Note.—If antimony is present the silver incrustation appears crimson. A surer test for silver than that obtained under 9 is to deposit the sublimate over an antimony film. Make such a film from antimonous sulphide, and gently heat at one side of it a particle of argentic nitrate. A crimson stain will appear in the direction of the blowpipe flame.

(*b*) *Treatment with nitrate of cobalt.*—When a white incrustation is formed, or when the substance itself remains white after heating in O.F., it should be moistened with a drop of nitrate of cobalt solution, the charcoal having been left a short time to cool. On reheating *strongly* in O.F. it

may on cooling assume some characteristic colour. The charcoal alone should first be tested in this manner, as many kinds showed coloured streaks on the drying of the nitrate of cobalt.

Colour.	Indication.	Example.
1. Bright or yellow green	Zinc	Zincic oxide.
2. Blue green	Tin	Stannic oxide.
3. Dull green of uncertain shade	Antimony	Antimonous sulphide.
4. Flesh colour or dull pink	Magnesia	Magnesia.
5. Blue	Alumina	Alumina.

NOTE.—A residue that has turned blue should always be examined with a lens, as silicates when fused give the same reaction. If *no* fusion has taken place the colour may safely be ascribed to alumina. As an example fuse a splinter of orthoclase which has been moistened with nitrate of cobalt.

2. *With reducing flame.*

(*a*) *Reduction to the metallic state.*—The results of this operation often determine the metal where the incrustation is indecisive; in some cases, as with blende, the incrustation itself is not developed until the mineral comes under the R.F. If reduction cannot be effected by the flame, aided by the charcoal only, the powdered substance should be mixed with carbonate of soda and thus fused, when a bead of metal may often be found on breaking up the residue in a mortar.

Nature of Metallic Bead.	Indication.	Example.
1. White, malleable, marks paper	Lead	Galena.
2. White, malleable	Tin	Stannic oxide.
3. „ „	Silver	Argentic oxide.
4. „ brittle	Bismuth	Bismuthous oxide.
5. Red, malleable	Copper	Cupric oxide.
6. No bead, or a mere fused globule of the residue	Zinc, iron, &c.	—

(*b*) *Change in magnetic properties.*—After reduction compounds of iron, cobalt, and nickel can be attracted by a magnet. If the residue itself shows no reaction, its powder should be tested. Experiment with chalybite, iron pyrites, cobalt oxide, nickelous oxide.

(*c*) *Test for sulphur.*—Fuse the substance with two or

three times its bulk of carbonate of soda in R.F. When the excess of soda has been absorbed by the charcoal, cut out the residue and lay it with a drop of water on a bright silver surface, such as a clean coin. If sulphur is present in any form, a black stain results. Common gas, however, contains sufficient sulphur to produce a similar effect, but the stain is much lighter than that obtainable from minerals. If gas is employed with the blowpipe fuse soda alone, and observe the brown mark upon the coin; compare this with the black stain produced with pyrites, galena, gypsum.

Reactions with Beads of Borax.

Fuse a little borax on a small loop of platinum wire until it forms a clear glassy bead. Take up with this while hot a little of the powdered substance, gradually increasing the quantity, and noting the colour of the bead while hot, after the first red glow has passed off, and when quite cold. An apparently opaque bead may often be rendered transparent by flattening out while hot between the pestle and the edge of the mortar.

To clean the wire—which must be carefully done after each experiment—heat the bead, detach it by a sharp shake of the hand, and scrape off what remains, washing the wire with hydrochloric acid if necessary.

Since these reactions are due to the metallic oxides in difficult cases (or before one can be certain that no definite reaction is obtainable) it is desirable to roast the powdered mineral in O.F. on platinum foil or charcoal. Very many substances give beads yellow when hot, and colourless when cold, or, in quantity, yield opaque white beads; but these are seldom of value for purposes of distinction.

Shake off characteristic beads, formed in the following experiments, into the mortar, thus preserving their globular form; arrange them as a series in a glass tube for comparison with the results obtained from minerals. The series may be numbered on a gummed slip of paper down the side of the tube in order to avoid eventual confusion.

Colour in O.F.		Indication	Example
Hot	Cold		
1. Blue . .	Blue	Cobalt	Cobalt oxide.
2. Green. .	Blue to green-blue	Copper	Cupric oxide.
3. Yellow to dark red	Yellow-green	Chromium	Chromic oxide.
4. Red . .	Yellow	Iron	Magnetite
5. Violet. .	Red-violet	Manganese	Manganic oxide.
6. Violet. .	Reddish to greyish brown	Nickel	Nickelous oxide.
7. Yellow .	Colourless	Tungsten	Tungstic anhydride (mix with borax in mortar).
8. Yellow .	Colourless to opaline	Molybdenum	Molybdic anhydride.
9. Yellow .	Colourless to opaque white	Titanium	Titanic oxide.
10. Red . .	Red-yellow	Uranium	Uranic oxide.

Colour in R.F.		Indication	Example
Hot	Cold		
1. —	As in O.F.	Cobalt	Cobalt oxide.
2. Green. .	Opaque red	Copper	Cupric oxide.
3. Green. .	Green	Chromium	Chromic oxide.
4. —	Bottle green	Iron	Magnetite.
5. —	Colourless	Manganese	Manganic oxide.
6. —	Grey and nearly colourless	Nickel	Nickelous oxide.
7. —	With large quantity straw to yellow-brown	Tungsten	Tungstic anhydride (mix with borax in mortar).
8. —	Brown	Molybdenum	Molybdic anhydride.
9. —	Yellow to yellow-brown	Titanium	Titanic oxide.
10. —	Green	Uranium	Uranic oxide.

Reactions with Beads of Microcosmic Salt.

This salt effervesces greatly when heated, and must therefore be added to the wire in small quantities until a clear bead is formed. It will be found convenient to fuse a quantity on charcoal or platinum foil until all the water is driven off, and, while hot, flattening the mass out in a mortar, afterwards

breaking it up; it can then be readily retained on the wire. If exposed to the air it ultimately deliquesces, so that it should be kept in a stoppered bottle.

A larger quantity of the substance is required to produce a good colouration than is the case with borax.

A series of beads for comparison may be arranged and sealed in a tube in the same manner as the borax beads.

a. Observe the following reactions :—

Colour in O.F.		Indication	Example
Hot	Cold		
1. Blue . .	Blue	Cobalt	Cobalt oxide.
2. Green. .	Blue to green	Copper	Cupric oxide.
3. Red . .	Green	Chromium	Chromic oxide.
4. Yellow to red	Colourless to brown-red	Iron	Magnetite.
5. Violet. .	Red-violet	Manganese	Manganic oxide.
6. Red to brown	Yellow to orange	Nickel	Nickelous oxide.
7. Yellow .	Colourless	Tungsten	Tungstic anhydride.
8. Yellow-green	Green to colourless	Molybdenum	Molybdic anhydride.
9. Yellow .	Colourless	Titanium	Rutile.
10. Yellow .	Yellow-green	Uranium	Uranic oxide.

Colour in R.F.		Indication	Example
Hot	Cold		
1. — .	Same as in O.F.	Cobalt	Cobalt oxide.
2. Dark green.	Opaque red	Copper	Cupric oxide.
3. — .	As in O.F. but darker	Chromium	Chromic oxide.
4. Colourless to red	Colourless to reddish	Iron	Magnetite.
5. — .	Colourless	Manganese	Manganic oxide.
6. — .	Nearly colourless	Nickel	Nickelous oxide.
7. Dull green .	Blue to blue-green	Tungsten	Tungstic anhydride.
8. Dull green .	Chromium-green	Molybdenum	Molybdic anhydride.
9. Yellow .	Violet	Titanium	Rutile.
10. Green. .	Bright green	Uranium	Uranic oxide.

NOTE.—A brown to crimson bead in the R.F. indicates tungsten and iron or titanium and iron. Experiment with a

mixture of magnetite and tungstic anhydride, and also magnetite and rutile.

b. Examination for silica.—The silica contained in any mineral remains undissolved in microcosmic salt, though soluble in borax; it is usually seen as a white particle, retaining the form of the splinter—which should be quite small—originally introduced into the bead. Long blowing is required before one can be certain that the residue is actually insoluble and is therefore due to silica.

Treat first with borax, and then for comparison with microcosmic salt, quartz, orthoclase, hornblende.

Reaction with Bead of Carbonate of Soda.

Colour in O.F.—Opaque green. *Indication.*—Manganese. Try with minute quantities of manganic oxide. In practice this test is somewhat delicate, and manganese is not likely to be present as an essential constituent of the mineral under examination, where no reaction is obtainable with borax or microcosmic salt. Where, however, these reactions are masked by the presence of other oxides, as in wolfram, the soda bead becomes of value.

SECTION VI

PROSPECTING, ETC.

CHAPTER I

Prospecting, Developing, etc.

In the previous sections we have described in simple language the chief chemical laws which govern the combinations of inorganic substances, the chief minerals and rocks which occur in the earth's crust, and simple methods of ascertaining their nature and value. In addition, the geological history of the earth and the various causes which have been instrumental in modifying its appearance from time to time have been given. It must not be supposed, however, that a mere book knowledge will enable anyone to become a good geologist, mineralogist, or petrologist. Each of these is a science of practical observation, to which the book is but as it were a catalogue. A fair knowledge of each of these sciences is necessary for economical and successful prospecting, and it is hoped that a careful study of the foregoing sections, combined with actual experience in the field, will enable the student not only to become conversant with any mineral or rock he may find, and to understand the outlines at least of the geology of the country he traverses, but that the knowledge gained by its aid will be the first step towards the collection and tabulation of practical information, which, besides being interesting and profitable in itself, is of the highest value to, and for the ultimate profit of, all mankind.

Let the prospector ascertain with certainty the nature of each rock and mineral he comes across; let him note the leading particulars and details of its occurrence, what are the adjacent rocks, if they are broken up or fissured, and, in short, enter in a book for future reference all such details as appear

to be advisable. The circumstances will vary in each case, and therefore it is not possible to lay down any definite rules. Let him be guided in each case by the conditions and surroundings. In a short time he will have a mass of most useful information which will assuredly save him from many a weary tramp or many a fruitless errand. It is perhaps not too much to say that prospectors ought to be (but how seldom they are!) amongst the best practical geologists and mineralogists; their opportunities for acquiring and tabulating information are endless.

A prospector's kit.—In this section will be seen a plate upon which is shown some of the most useful of miners' tools and gear. The outfit required by a prospector varies so much in every case that it is not advisable to go into details of the heavier articles he will require. But in order for him to test minerals and rocks, ascertain heights, levels, and directions, &c., the following will be found useful and not cumbersome:—

- A small set of blowpipe apparatus as set forth in Section V.
- A prospecting hammer weighing 2½ lbs., having the handle marked off in inches.
- A prismatic compass.
- An Abney's level, or a clinometer.
- A small but accurate aneroid barometer.
- A good strong note-book.
- A leather bag with pockets for samples, or a few small canvas bags with strings attached, so that the necks may be secured.

This may seem a formidable lot, but as a matter of fact they will all go comfortably into a small leather sling-bag.

Armed with these few articles and a handy guide-book, the prospector should be in a position, with very little practice, to determine many of the minerals and rocks he may find.

Let us see how he would proceed.

Testing Minerals or Mineral Veins.

A vein of clear white rock is found, with some dark-looking mineral running through it, the white rock evidently form-

ing the gangue of a vein. With the heavier hammer the prospector knocks off a piece from the vein. Trying first the hardness of the mineral with his knife or file on a fresh fracture, he finds that it makes very little or no impression upon it. Now he knows that the gangue of veins (see Mineral Veins, page 146) is usually either quartz, calcspar, barytes or fluorspar. He knows also that according to the scale of hardness quartz is No. 7, and is with difficulty or not at all marked with a knife or file; while calcspar is No. 3, and is easily marked (see Mineralogy, page 22). He is also aware that the hardness of fluorspar is No. 4, while the hardness of barytes is less even than that of calcspar. The inference is that the gangue of the vein is quartz.

But a confirmation of our inference is necessary. How about colour? All these minerals are usually white or colourless, so that in this case colour is no guide. Let us try an acid test. Calcspar effervesces in hydrochloric acid, but this mineral does not, *therefore it is not calcspar*; fluorspar crumbles away before the blowpipe (see Mineralogy, page 60), but this mineral is infusible and unaltered, *therefore it is not fluorspar*; barytes, in addition to its high specific gravity, gives a green colouration to the blowpipe flame, but the mineral under examination gives no colouration to the flame, and is of about the ordinary specific gravity of a rock. This series of tests proves conclusively that the veinstone is *white quartz*.

But the vein contains what are apparently two metals running in fine strings through it. The one, A, is of a lead-grey colour; the other, B, being very like it, but darker. Separating a small piece of each from the gangue, he tries the hardness, which he finds to be for A 2·, and for B 2·5. He learns little from this, and not much in addition by trying the streak, for in both cases he gets a shining metallic streak the same colour as the ore. He then tries A on a piece of charcoal before the blowpipe. In a very few moments, in addition to the white fumes and sublimate characteristic of antimony, he gets a sulphurous odour, and with a little more blowing the whole frequently disappears. From these results he concludes it to be stibnite (antimony sulphide), for on

reference to his notes on mineralogy he finds that mineral agrees in all particulars with the one under examination. He then proceeds to try the fragment B before the blowpipe. An odour of sulphur tells him that sulphur is present, and on charcoal, with a little persistent blowing, he gets a small globule of a silver white metal, malleable, and harder than lead. He knows therefore that it must be either silver or tin, and the nature of the sublimate decides that it is the former. The ore is therefore a sulphide of silver. He turns to his notes on mineralogy and finds that the mineral argentite agrees in all particulars with the one under examination, and for safety adds a few confirmatory tests.

In such a manner as the above, noting hardness, colour, specific gravity, cleavage, and the behaviour before the blowpipe, the student will soon be able to identify any mineral he may find, and often from that best of all tests—experience—he will be able to immediately recognise minerals, no matter in what disguise they appear.

Testing Rocks.

Testing and ascertaining the nature and classes of rocks is a much more difficult matter, and a knowledge of them is best acquired by frequent handling of labelled specimens. Many of the rock-forming minerals, such as mica, hornblende, the feldspars, and quartz, are not difficult to remember and identify, but when they are combined in a close-grained, compact rock, often varying in colour, they are with difficulty distinguished, and hence the nature of the resulting rock is not easily ascertained. A good lens will often prove of valuable assistance.

The most satisfactory and exact method of determining the constituent minerals and nature of a rock is by an examination of an exceedingly thin and specially prepared section with a microscope made for the purpose; but this method is one which requires special knowledge, and to which the prospector need never have recourse.

The prospector will in most cases be satisfied, and justly so, by ascertaining the class to which a rock belongs. Limestones are always recognised by their effervescence in dilute

acid and by the ease with which they are scratched; while sandstone, shale, slate, gneiss, granyte, dioryte, basalt, felsyte, conglomerate, and the schists are all readily known by their constituent minerals, structure, colour, &c. Perhaps it would be well if he did not in the first place trouble about the exact species, so long as he is able to ascertain the class to which the rock belongs. The main desire should be to distinguish between the sedimentary or stratified rocks, the metamorphic and those of igneous origin.

Testing Gems.

Gems of different species and greatly different value often resemble one another closely, and require careful testing to identify them. Some garnets are found resembling rubies. Quartz crystals and diamonds might easily be mistaken by the uninitiated for one another, and over emeralds and green tourmalines frequent mistakes have been made. The crystalline form, specific gravity, hardness, and careful tests with the blowpipe will usually enable the prospector to identify any gem-like stones he may come across.

The values of different minerals.—It may safely be said that one of the great mistakes made by explorers and prospectors is the rush after gold, to the utter neglect of all other minerals and gems. Ores of silver, tin, mercury, lead, zinc, copper, &c., and gems such as diamonds, rubies, emeralds, sapphires, opals, cats-eyes, &c., are all valuable, and the working of them likely to prove much more profitable than gold-mining. Coal and petroleum are both of great commercial value. It is therefore most desirable that prospectors should make careful tests of everything they find which they deem likely to be of value, and that they should never leave a mineral lode, a deposit of gem-like stones, or any indications of oil on the surface of water or on the ground, until they have thoroughly satisfied themselves that the vein or deposit is of no value. Many of the carbonates, phosphates, and silicates do not look in the least metallic, yet they may prove to be of the greatest value. A prospector should never discard a lode because he can see nothing of value in it, or because he has seen in another district others like it that

were barren or valueless. Many of the most valuable gold deposits do not show any gold to the naked eye. Give everything a careful and impartial test, and remember that the processes by which Nature has endowed the earth with valuable minerals and gems are many, and man is yet ignorant of the method and means by which many of these treasures were formed.

Prospecting in alluvial deposits.—Some of the most valuable storehouses of Nature have been unearthed in alluvial deposits. Gold, platinum, tin, and many gems are found in them, and they offer, on account of the facility with which they can be worked, great chances of speedily acquired profit.

Alluvial deposits are of two kinds, *shallow placers* and *deep leads.*

Shallow placers are recent alluvial deposits lying immediately upon the country rock. They are simply the accumulation of detritus washed down from a parent formation on higher ground.

Such deposits containing gold will be found richest where the current of the stream depositing them has met with obstruction, causing a diminution of its velocity, round sharp bends or curves, or in hollows and crevices of the bed rock. Fig. 108 shows conditions under which payable placer deposits may have accumulated.

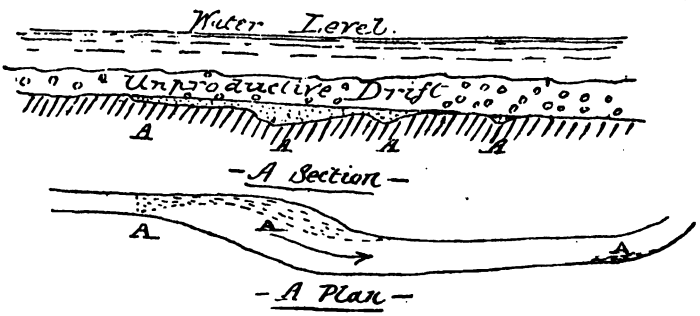


FIG. 108.—A Plan and Section of a River Bed, showing conditions under which payable Placer deposits accumulate.

The working of various placer deposits in different parts of the world shows that they may be from a few inches in depth up to several hundreds of feet; and further, although the

bottom layer of all, that lying on the bed rock or decomposed bed rock, is generally the richest, or what is called the 'pay-streak' or 'pay-dirt,' other strata above may also be payable. Figs. 109 and 110 show two sections of payable alluvial

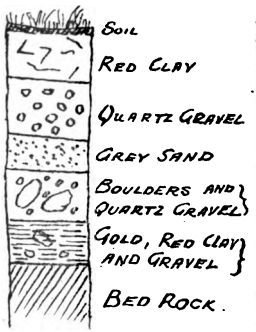


Fig. 109.

Fig. 110.

gold placers. Favourable places in which to look for alluvial gold deposits are difficult to describe, and the prospector will be best guided by his own careful observations and experience. On beds of dry creeks, at the bottom of deep gorges, in old and disturbed strata, on wide-reaching alluvial flats which show ancient river terraces, and in the alluvial wash beside existing rivers, he may at any time come across valuable gold deposits. The value of such deposits will largely depend upon the facilities which are at hand for working them. The chief need for working placer deposits is water. Without a good supply of water near at hand, to which the pay-dirt can be cheaply and speedily carted, or which itself can be led on to the ground, many rich placer deposits may be quite valueless.

Deep leads.—Placer deposits, as described above, are alluvial deposits which have been accumulated, and are accumulating, within an existing watershed. *Deep leads* are similar deposits within the limits of a watershed once existent, but which is now greatly modified owing to alterations in the surface of the earth.

Deep leads are, in fact, auriferous gravels which are now

covered, maybe, by hundreds of feet of consolidated sedimentary or igneous rocks.

Such leads are shown in fig. 111. In this section it will be seen that the old river-beds A A, with their pay-dirt streaks,

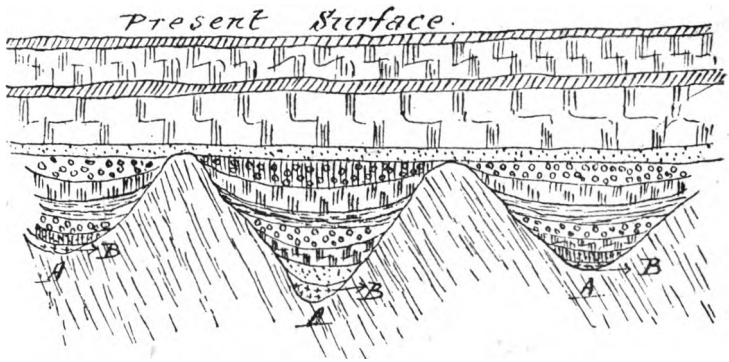


FIG. 111.—A Victorian Deep Lead.

B B, are now overlain by a great mass of basalt, as well as stratified rocks, which have been instrumental in entirely altering the aspect and drainage of the country.

It is obvious, in the first place, that to explore such leads is a matter of time and money, which it would, in the majority of cases, be unwise for those with small capital to undertake. In fact, extensive prospecting for deep leads should never be undertaken except under the advice of a thoroughly competent alluvial miner, who will be able to judge of the expense and time necessary to carry out the work, and to form some estimate of the probability of payable ground being struck.

Lock on 'Gold,' page 909, says, in connection with this matter: 'Rarely is it possible to trace the course of a deep lead within such limits as will serve the turn of the gold-miner merely by the indications furnished by the natural surface of the land overlying them. The course of a channel originating in a range of Palæozoic rocks may for some distance be well marked by strata of gravel, sand, and water-worn quartz pebbles filling up the lower part of the valley; but when it is followed out into the low plains through which the modern stream has cut its way, the strata may, and

almost certainly will, increase in thickness, so that it becomes impossible any longer to follow the trend of the ancient river-bed. By noting the direction of the boundary ridges it may be possible to indicate the limits of the deviation of the channel; but where the distance between them is considerable, which is very generally the case, much money may be fruitlessly spent in sinking in search of the lead. When a lead is overlaid by basalt the miner's difficulties are increased.

'In some localities, it is true, the direction can be determined within limits sufficiently restricted for theoretical purposes, because the outcrops of the bed-rocks are visible on either hand, and their elevation above the valley or plain can be fixed. But to the miner only two courses present themselves: if he will ascertain the course of the lead with accuracy he must undertake expensive subterranean explorations; approximately, he may succeed by putting down borings. Yet, even when the general trend is known, and the width reaches a mile or two, nothing is easier than to miss the richest part of the lead. The undulations of the surface afford no clue, and are often very misleading; and when the lowest depressions of the underlying strata have been found at the expense of boring, it may chance that the richest deposits of gold do not lie there, but in the "reef-washes" or "benches" at the higher levels. A "reef-wash" is a deposit of wash-dirt spread over an expanse of flat or undulating "reef" or bed-rock, or lodged in a hollow in it above the level of the "gutter," or true vein of the watercourse. For instance, towards the junction of two leads the wall of reef or bed-rock by which the two leads are separated appears in some cases to be worn or broken down, and a stretch of comparatively flat rock is left between them. If covered by a layer of wash-dirt, and raised above the level of the watercourses, this would be called a "reef-wash." Also, where the rock on one side of the watercourse spreads out at a higher level, and a channel containing wash-dirt is found running alongside the true gutter, and between the gutter and the wall of the bed-rock, it is called "reef-wash."'

In prospecting deep leads, all the cements or conglome-

rates, sands and gravels should be carefully tested, for they not infrequently carry gold in payable quantities.

The prospector may look for deep leads where he finds Tertiary strata overlaid by basalt, lava, or other igneous rock. Many of the richest leads which have been found have occurred in this manner.

Platinum.—Platinum, palladium, and others of the rare metals of this group, either separate or together, are found in grains and masses in alluvial deposits, often in connection with alluvial gold. All these metals are of great value, and any metallic grains the prospector may find in alluvial sands and washes should be carefully tested.

Stream tin.—Deposits of stream tin (cassiterite) occur in grains in alluvial and drift beds. In the island of Banca, and also in Cornwall, valuable deposits have been found in these surface detrital strata. Fig. 112 shows a section through the strata overlying an alluvial tin deposit.

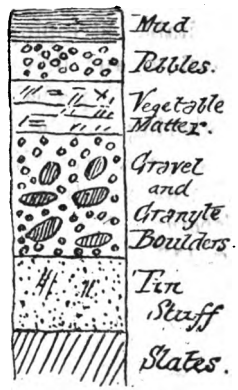


Fig 112.

Gems.—Diamonds are found in crystals in alluvial deposits in Brazil, India, and South Africa.

Sapphires occur in alluvial deposits below mica schists and granular limestones.

Rubies and emeralds are met with occasionally in alluvial drift below granyte, gneiss, and mica schist, and sometimes granular limestone; while many of the inferior gems, such as cats-eyes, garnets, onyx, cornelian, and topaz, are also found in dry river sands and gravels.

How to reach alluvial deposits.—In many places the depth of these deposits is so small, and the nature of the overburden so soft, that the process called *stripping* is resorted to in order to get at the payable drift below. This consists, briefly, in opening up a certain patch over the deposit and laying bare the pay-dirt, which is then worked away by sluicing, either by bringing the water to it or by taking it to the water. When one patch is worked out and

all the pay-dirt treated, the over-burden from the second-patch should be put into it, in order to keep the ground as level as possible, to prevent floods and incursions of water. No rule can be laid down for the ultimate depth to which 'stripping' can be profitably applied; it must depend on local circumstances; but its advisability or otherwise can usually be readily determined.

In cases where it has been ascertained that the pay-streak is too deep down, or the over-burden too hard to allow of profitable stripping, ordinary mining, by means of shafts down to, and drives along, the pay-streak, must be resorted to. It will probably be found in many cases that special timbering will be required to contend with inflowing water and loose, crumbling strata in these deposits. To contend with watery strata, it is best to adopt the process known as *slabbing*. This method will be understood by reference to fig. 113.

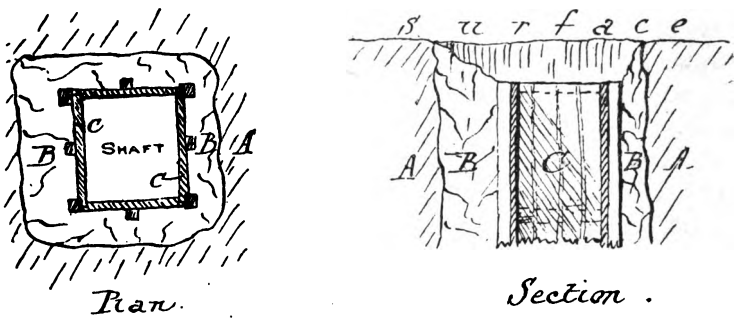


FIG. 113.

A similar system may be employed for keeping water out of wet drifts along the pay-streak.

Testing alluvial deposits.—Panning.—One of the simplest methods of testing gold, platinum, or tin alluvial deposits is by means of the 'prospector's pan.' This pan is made in the form shown in fig. 114, stamped from a piece of sheet iron, so that it is in one solid piece. It should be about ten inches diameter at the bottom, and about fourteen inches at the top, and should have an indentation or groove running round it within an inch of the upper rim.

A quantity of the dirt to be washed is taken and the pan half filled with it. The pan is then filled with water and the contents are thoroughly stirred with the hand. The operator then grasps the pan firmly on either side and pours off two-thirds of the now discoloured water. He then nearly fills the pan again with clean water, and with a gentle circular rocking motion, and with the farther edge of the pan slightly tilted downwards, he allows the water to flow off (into another empty pan, so that nothing may be lost in case of an accident), carrying with it all the finer and lighter sediment. Before the water has all quite gone he refills it, and goes through the same process again, this time, however, allowing the still water in the second pan to sip away the extreme front of the dirt in the pan he is operating. With increasing care, as the amount of material gets less, he continues the operations of refilling with water, oscillating, pouring off, and sipping away until at last nothing remains in the pan but the heavier mineral and metallic particles which accumulate around the bottom of the pan.

FIG. 114.—Prospecting Pan, or Dish.

These metallic contents may be valuable or worthless. In the former case, the worth of the ground is judged by the length of the 'tail' left and the size of the particles.

Where the contents of pan are valuable the prospector is advised never to pan into a river or stream, as some, or the whole, of the contents may be lost beyond recovery. If two pans are not handy do the panning into some receptacle, such as a bucket or tub, or even into a hole among rocks, or a pool in a river, which can be readily emptied.

In cases where the panning is being carried out on uncrushed alluvial débris, the large stones should be removed with the hand during the process of panning; but where samples from lodes are being panned, the ore should be crushed in a mortar and the whole passed through a fine sieve into the pan.

This method of panning will answer as a sampling method

for, and even in some cases as a means of recovery of, alluvial gold, platinum, or tin.

In the case of prospecting for gems it is desirable to first pass the gravel through a coarse sieve and subsequently to 'size' it by a number of sieves of different mesh, afterwards examining each lot of gravel or fine pebbles by spreading on a table or cloth, when anything of value can be easily recognised and withdrawn.

If it is wished to collect the fine gold-dust resulting from a panning of auriferous dirt, a little mercury should be put into the pan, with a small piece of potassium cyanide, and the whole incorporated with the residue in the pan. The mercury takes up the gold, forming *amalgam*, which can be separated from the heavy sand by washing. The excess of mercury is then separated from the amalgam by squeezing through chamois-leather, and by heating the amalgam the mercury is driven off and a spongy mass of gold obtained.

Sluicing.—The prospector may be desirous of treating the pay-dirt in bulk and not only in small quantities in a pan. In such a case, it will be necessary for him to resort to the process known as *sluicing*. The methods adopted and the sluices used are numerous, but they all depend upon the principle of gravity; that is to say, the metals and metallic minerals, being so much heavier than the non-metallic, are arrested, the latter being washed away by an adjustable current of water.

The *tom* (fig. 115) is, in principle, a form of sluice, although it is not usually described as such. It is made out of rough plank of the pattern shown. Water is introduced by the trough A, and the dirt is thrown into the trough B, which is closed by a perforated sheet of iron at *b*. The dirt is constantly stirred by a man or boy, and the stones, &c., which are arrested by the iron screen, are thrown away, while the finer particles pass through and the heavier ones are caught in the riffle box D by means of the riffle bars *d d*. Sometimes a little mercury is put into the riffle box to aid in arresting the gold. A constant and even flow of water is maintained to wash away the sand, clay, and sediment. *Toms* are generally supposed to be out of date, but they are little expense to construct, useful in

arresting coarse gold, and get through a considerable amount of work.

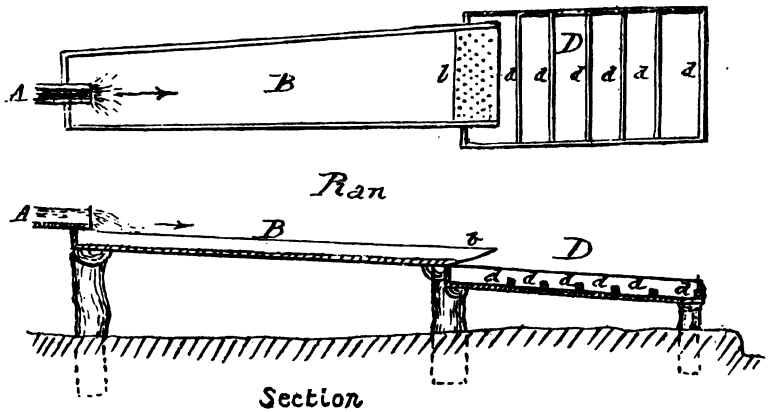


FIG. 115.—Washing Tom.

Zigzag sluice.—This consists of an inclined trough or series of troughs—the latter is preferable because more easily removed—which are graded about 8 inches in 12 feet. The length varies from a few up to as many as 150 feet. At intervals there are fixed across it laths of wood, which should be sawn crossways to the grain so as to withstand the wear and tear. They (*a a*, fig. 116) are the riffles which assist in retaining the gold. The whole is terminated by a longitudinal sluice with a false bottom, c (fig. 116), to still further assist

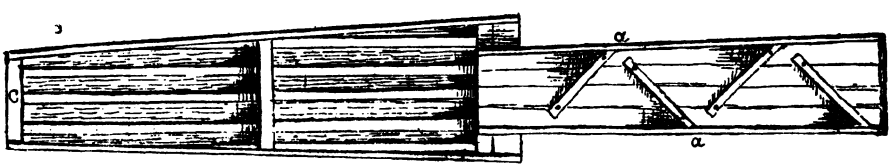


FIG. 116.—Plan of Zigzag and Box Sluice with False Bottom.

in arresting the heavier particles. When the gold is fine, mercury in small quantities is added at the top of the zigzag sluice, and the amalgam is caught in the false bottoms of the sluice lower down. The dirt is introduced at the top of the sluice, and water is led on to it from a ditch or flume. The

gravel, sand, or clay is thoroughly disintegrated by means of a prong fork, while all the big stones are pitched out by the same instrument, the supply of water being regulated to suit the nature and amount of dirt being passed through.

The zigzag sluice combined with the *plain* sluice with false bottom is a well-tried, simple, and fairly satisfactory apparatus for the recovery of alluvial gold.

Prospecting for mineral veins.—In the sections on Mineralogy and Geology reference has been made to the formations which are likely to contain payable mineral veins, but it will be well here to enter somewhat more fully into the indications which may lead to a discovery of the same, and the evidences which point to the inference that payable deposits may exist in certain districts.

The first evidence of the probability of the discovery of payable minerals is the existence of other deposits which are being worked with more or less satisfactory results in the neighbourhood.

It is rare indeed that one vein or other form of deposit exists in a district without there being others of a similar nature. In some mineral districts there is a distinct tendency for veins to lie in two directions at right angles to each other. Where this double line of deposit does not exist the veins will usually be found to arrange themselves in a series of *parallel* lines.

As with existing workings, so with ancient ones. The presence of ancient mine workings, as shown by disused shafts and drives, heaps of débris, ruined houses, and dressing-floors presuppose the existence of mineral veins and deposits in the district; but the probability is, that they tell no story of the reason for their abandonment. In the case of many metals—tin, copper, and lead, for instance—it may not be due to the actual poverty of the lode so much as to the fact that these metals decreased in market value to such an extent that the mines could not be worked with profit at the time they were abandoned, or the inflow of water may have been so great that with the means at disposal it could not be kept down. On the other hand, it may be that the deposits gave out, or that the country was occupied by some political enemy of the

workers. The true reason will often be unsolved, but whenever possible any old workings found should be entered and carefully examined.

A knowledge of geology will largely assist the prospector in coming to a right judgment as to the probability of the presence of mineral deposits, for he will know in what formations certain deposits are usually found. It is true that geology is a book which is yearly receiving fresh chapters on new occurrences of deposits valuable to mankind; but in no wise do they upset the existing facts as established in other parts of the world. It is a common expression in new countries—especially in South Africa—to say that 'the geology is upside down;' but such statements are usually made by ignorant persons or upon inconclusive and unreliable evidence.

The presence of tourmaline or schorl granyte, especially when slates are found in the district, points to the probability that tin or copper lodes exist. The millstone grit presupposes the existence of coal beneath, and highly tilted Silurian slates, ruptured and fissured in many directions, are surely worth examining for gold-bearing quartz veins. The prospector should always carefully note the geology of the country he is traversing.

The strongest positive evidence—save that of the actual outcrop—of the presence of mineral lodes in the vicinity is to be found in the fragments or portions broken off from the main body and scattered down hillsides and over the floors of the valleys. The beds and sides of rapid rivers form receptacles for scattered fragments and grains detached from the hills within the watershed.

If anything of value be found, or any indication of valuable minerals be noticed, the prospector should ascend the bed of the stream until he traces the fragment to its home in the hills beyond. Great care should be taken to examine the bed of the river from time to time, more especially where tributary streams enter the main stream, in order that he may ascend the right valley. An idea can usually be formed of how far a fragment has travelled by its angular, subangular, or rounded appearance, for the greater the distance a stone has travelled the more rounded will it be found.

With reference to the outcrop of lodes, it may be noted that they are easy of recognition, for they are of a different nature to the enclosing rocks, and usually weather in a greater or less degree than the surrounding country. In the latter case they stand out above the surface, and in the former the outcrop is marked by a trough or hollow along the strike of the lode.

First explorations.—Let us now suppose that, by one or other of the evidences described above, the prospector has been led to the actual discovery of a mineral lode. We do not here say anything about testing the lode as to its payable nature, for the various processes adopted for the testing or assaying of minerals have been described in previous sections, and we are presupposing that the prospector, after taking into consideration all the circumstances of the case (facilities for working, wood, fuel, labour, water supply, a market for the product, transport of provisions to, and ore from, the mine—all such considerations carrying, of course, different weight in different districts), is satisfied that the find is worth developing. Having decided in the affirmative, his first care will naturally be the acquisition of a piece of ground enclosing his find in what he considers the most profitable manner. In order to do this (supposing it is a lode), he must first trace the outcrop or strike. Sometimes the outcrop is clearly traceable on the surface, in which case it presents no difficulty. In others it is only to be seen here and there, when the gaps can be readily filled in by an observant man, due attention being paid to the occurrence of any dislocations or faults, which in some cases may throw the lode many yards to one side or the other. In a third case, it may only be seen at one point; here trial pits or cuttings will have to be made to determine its line of strike. In some instances the strata which form the walls of the lode will be clearly traceable; in which case a correct conclusion can be arrived at concerning its strike. His next care must be to ascertain its dip. The dip should always be measured in a direction at right angles to the line of strike and from the horizontal, so that a nearly vertical lode will have a large dip, and a flat one a small dip. To ascertain the correct dip is a matter of

importance, for it will readily be understood how, under varying circumstances, a greater or less quantity of ore will be enclosed within the boundary lines. Where the lode is flat, as at A, fig. 117, the side lines will enclose but a small proportion of the lode compared to the amount at B, where the dip is steep. Hence the width of ground to be secured should be to a great extent regulated by the angle at which the reef dips, the width being increased as the angle is less. In order to arrive at an idea of the dip the prospector must carefully note the dip of the surrounding strata—if the deposit is interbedded—as shown in escarpments and outcrops near by; or, if he is not able to determine it in this manner, he had best sink one or two inclined shafts on the lode. As a general rule, to which there are frequent exceptions, interstratified deposits in sedimentary strata get flatter in dip with increase of depth, while true fissure veins maintain a more or less constant dip, unless they have been disturbed by earth movements. In the section on Surveying a description of a simple instrument—the clinometer—for measuring the angle of dip is given.

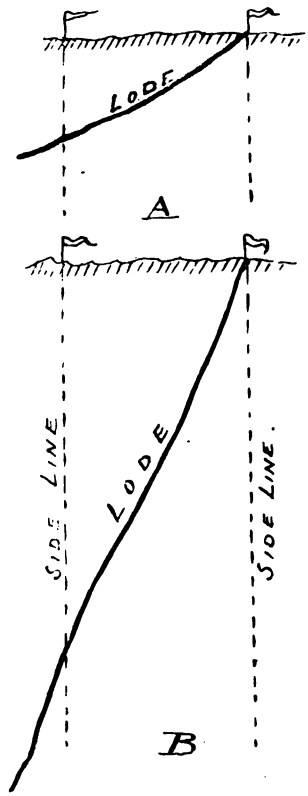


Fig. 117.

Having settled the area and form of his ground, and secured a title to it, his next proceeding will be to prove that the lode is persistent and lasting, and that the richness of the surface is maintained in depth. In rare cases a lode has been found to form the actual bare wall of the side of a deep ravine or gully; but it will generally be found necessary to sink shafts or drive adits to prove the lode. If the contour of the ground is steep, as shown in fig. 118, the driving of adits

from the side of the hill is to be preferred. It is not so expensive, and avoids the pumping and hauling incident upon shaft-sinking, entails a smaller outlay of time and money,

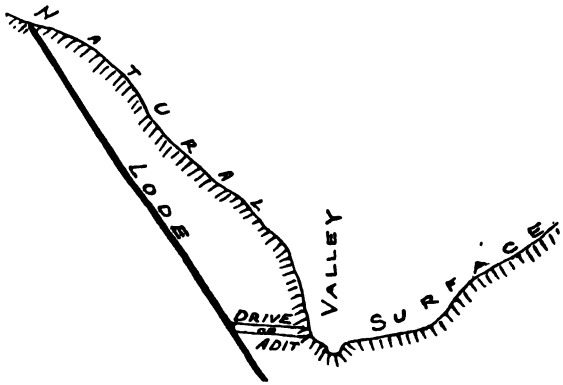


FIG. 118.

while a greater depth of lode is tested. If, however, the surface of the ground is fairly level, it is cheaper to sink an inclined shaft on the lode, or, if the lode lies somewhat flat, to put down a vertical shaft to strike it at a certain depth. In cases where the sinking of a shaft or the driving of an adit will test the lode at an equal depth, while both entail about the same expense, the adit is to be preferred; for, in addition to avoiding the use of pumping or hauling gear, it is not so liable to incursions of surface water, which with a shaft may necessitate the abandonment of the work for a longer or shorter period. Sometimes it will be desirable to sink several shafts and connect them underground by means of drives along the reef, so as to thoroughly explore the deposit.

Where the outcrop of a load is clearly traceable down the side of a hill, the more satisfactory way to attack the deposit will be to drive an adit into the hill along the reef, as indicated in fig. 119.

A table and diagram will be found in the next chapter, which will enable the prospector to ascertain the position in which to sink a shaft in order to strike a lode at any required depth, and also to calculate the length an adit will require to be driven for the same purpose.

For prospecting work shafts should be about 6 ft. × 4 ft. Adits and cross-cuts will be found of a convenient size for the same purpose if made 6 ft. high and 4 ft. 6 in. wide.

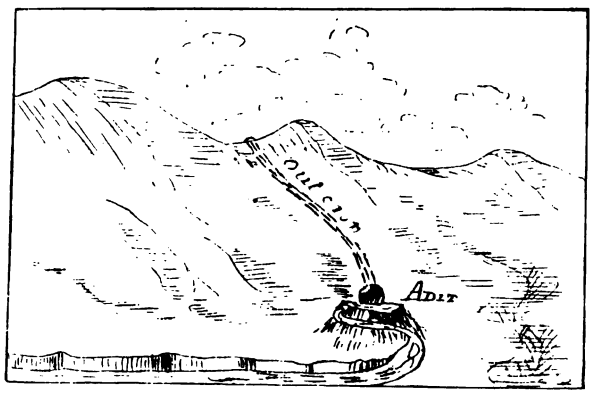


FIG. 119.

Timbering.—Not infrequently the prospector will be troubled by loose or crumbling strata, which, threatening to result either in the collapse of his shaft or the falling in of his tunnel, may also endanger the lives of the workmen. To obviate this it is necessary to resort to timbering or walling. Of these the former is the more general for rough explorations, as it is more easily and cheaply put up. Drawings of a few simple methods of supporting dangerous ground are here shown. A single prop is shown in fig. 120. It is let into the

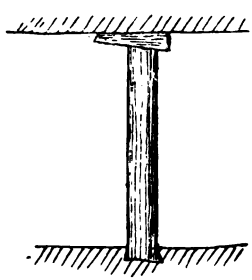


FIG. 120.—A Prop.

ground a few inches, and should then be driven into an upright position with a heavy mallet, and be firmly secured and

tightened up by means of a flat wedge driven in at the top. In erecting props of this kind care should be taken to place it at right angles to the surface which it has to support; otherwise the prop is at any time liable to slip away.

In an adit or level it will often be found necessary to put in complete frames or *sets* (fig. 121). The bottom piece or *sill* can often be dispensed with, and the side props let into the ground a few inches. B and C, fig. 121, show the form

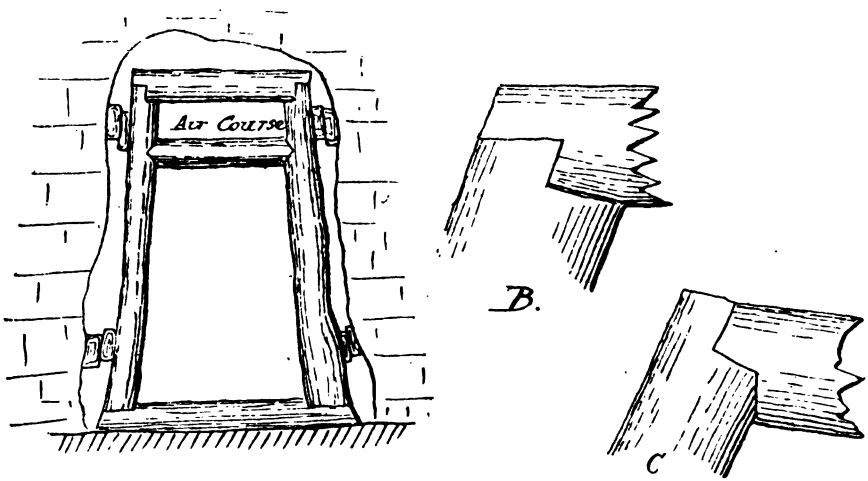


FIG. 121.—A Set.

of the joints that the upper angles should have; B is most suitable where a *downward* pressure is to be resisted, and C where the pressure is *from the sides*. The sets are fixed firmly in their place by means of wedges driven in between the wall and the set. The above frame may be made of different shapes and sizes to suit different circumstances.

A simple method of timbering prospecting shafts by means of rough timber is shown in fig. 122. The frame is lowered and fastened in its place, and, if necessary, *lagging* is placed at the back to prevent loose stones and earth falling away. Ladders, where possible, should always be used as a means of ascent and descent, and never, if it can be avoided, fixed in a vertical position. Where they are employed the shaft

should be divided into two compartments, as shown in fig. 123.

Timber should be examined from time to time to ascertain that it has not been broken by pressure or decayed by dry

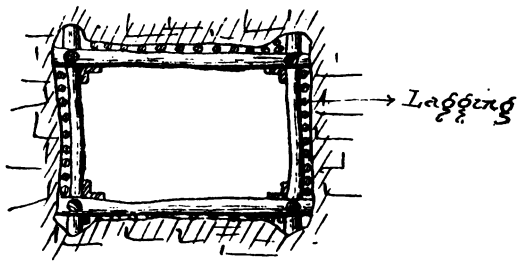


FIG. 122.—Prospecting Shaft, timbered.

rot; if such is the case it should be removed and replaced by fresh. In some countries ants are found to destroy timber very rapidly.

Should timber of suitable strength and size be unavailable, the prospector will be obliged to use stone for walling in any

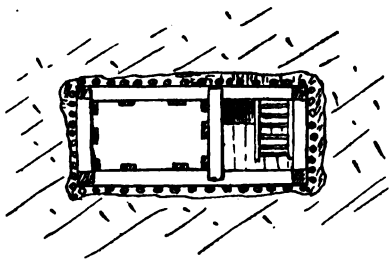


FIG. 123.—Two-compartment Shaft.

loose ground. Where ground looks like falling, or has been shaken loose by blasting, it should be removed with the pick, and the space between the masonry and rock tightly packed with clay and rubble.

Examples of masonry supports are shown in fig. 124.

Miners' tools.—The tools which a miner requires are not numerous, but it is necessary that they should be of good quality, and of such size and shape as to render them of use for the purposes for which they are intended.

Picks (fig. 125) are used for breaking out ground. They are made in various sizes according to the work they have to perform. A is an ordinary navvy's pick for breaking up soft

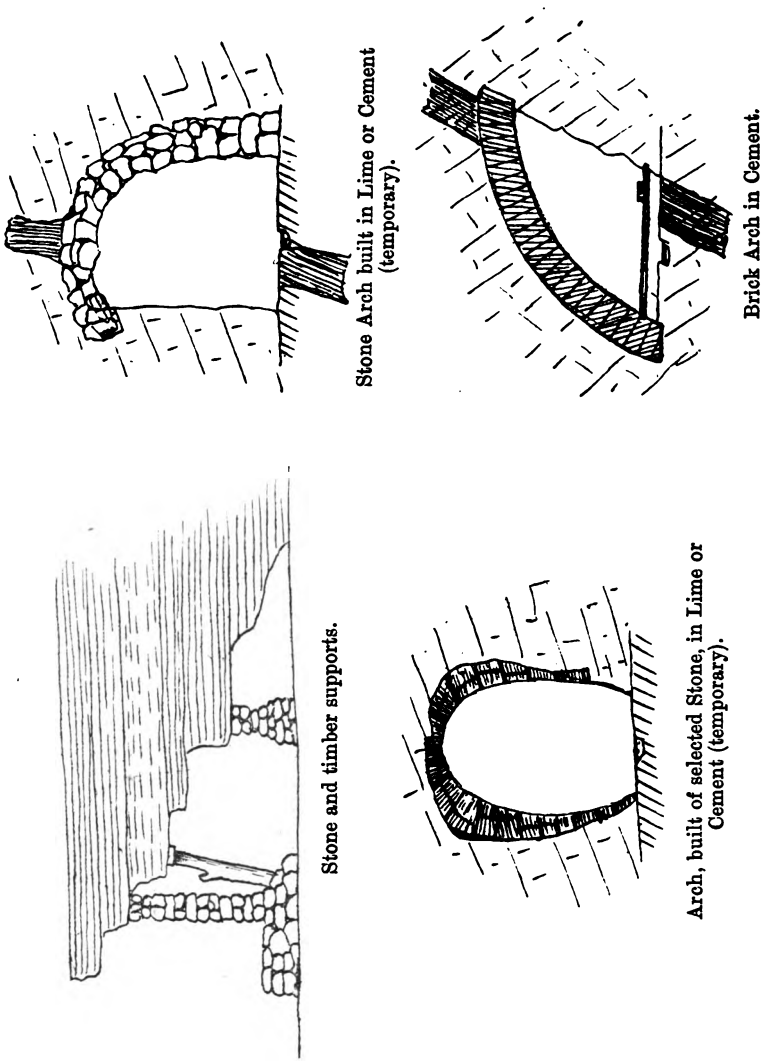


FIG. 124.

ground. In order to assist in cutting clay or other soft tenacious material, it should have one point flat like a chisel.

B and C are two forms of miner's picks somewhat lighter than the above. They are employed for breaking up and dislodging loose pieces of metal.

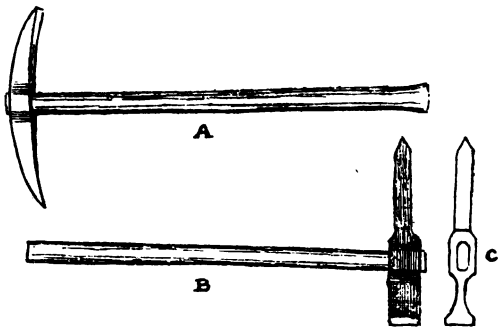


FIG. 125.

Shovels are shown in various forms in fig. 126. They should be about 9 in. wide and 13 to 14 in. long, and, when

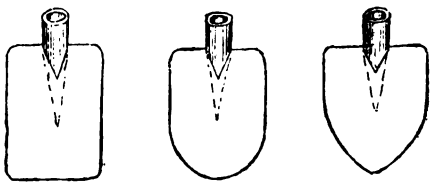


FIG. 126.

used for removing broken pieces of rock, should taper nearly to a point.

The handles of both picks and shovels, as well as hammers,

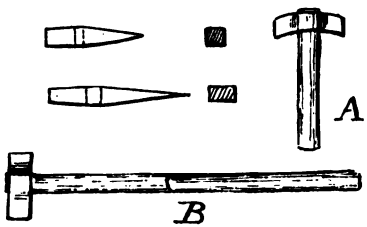


FIG. 127.

are best made of well-seasoned ash or hickory, free from knots.

The best forms of hammers are shown in fig. 127. A is

about 4 lbs. weight, with a handle 14 in. long, and is used for driving in gads. B should be about 7 lbs. weight, with a handle 18 in. to 22 in. long. It is used for striking the drill.

Gads, as shown in fig. 128, are used as wedges for loosening pieces of rock already partly dislocated.

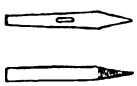


Fig. 128.—Gads.

Fig. 129.

Drills of various lengths, made from $\frac{7}{8}$-in. best round or octagonal steel, are used for drilling holes in hard ground, which are afterwards charged with dynamite or some other explosive. One end of the drill should be sharpened, as shown in fig. 129, and tempered so as to render it exceedingly hard, without being brittle.

Scrapers (fig. 130) are made of $\frac{3}{8}$-in. round iron, at one end of which a small disc is forged, the other being wrought to a point. They are used for cleaning out the mud or dust from the drill-hole.

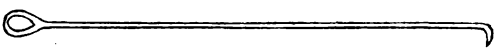


Fig. 130.—Scraper.

Tamping bars should always be made of wood. They are employed in ramming the charge 'home' in the drill-hole, and for compressing the sand or clay used in filling up the hole above the charge.

Blasting.—The operation of blasting has to be resorted to when the rock to be excavated is so hard that it resists the attack made upon it by means of the pick or gad. It is a process which if carefully conducted is attended with little or

no personal risks, but if carelessly done serious accidents may result. Before the rock can be blasted away a hole must be drilled in it. To do this all loose rock round the spot where the hole is to be bored is first removed. Care should be taken not to drill along lines of fracture, for in such a case little work is done by the explosion; on the other hand, too much anxiety to blast down a large amount at a time may result in the charge being unable to move the rock, and a 'blow-out' will result.

Care should be taken to rotate the drill slightly after each blow of the hammer, so that a perfectly circular hole may be obtained and wedging or 'jamming' of the drill avoided. In most rocks it is advisable to use water in the drill-hole, the mud formed being removed from time to time by the scraper. This mud may, in some cases, be tested as a sample of the ore being worked.

No rule can be given as to the length and direction to which holes should be drilled. Observation of the effects produced by certain charges on the ground being worked is the best guide. Holes from two to three feet deep will usually be found to give satisfactory results.

When the hole is finished, it is well cleaned by means of the scraper, and one, two, or more dynamite cartridges rammed tightly to the bottom of it. In the last cartridge the fuse with the detonating cap attached is placed. The end of the fuse which is inserted in the cap should be cut off square and pushed into the cap as far as it will go, the latter being firmly attached to the fuse by squeezing the upper part with a pair of wooden pincers or between two blocks of wood. A common but dangerous practice is to pinch the cap *with the teeth*. The cap, with fuse attached, should be carefully pushed into the dynamite up to the top of the cap, *but not further*, and the whole is then placed in the hole and gently pushed into position with the tamping bar; sand or other loose earth is now added until the hole is full, each addition being rammed down. A slit about ½ inch deep is made in the end of the fuse projecting, a little dynamite placed in it, and, a light being applied, the miner retreats to a place of safety.

If the whole happens to be drilled in a wet place a water

tamping should be used. In such a case care must be taken to make the junction of the cap and fuse perfectly watertight by means of grease. Ordinary good double-tape fuse will be found waterproof if the operation is conducted expeditiously.

New fuse should always be tested by cutting off a piece two feet long and observing the time which it takes to burn out after ignition. If this is not done, accidents, caused by the premature explosion of the charge, are liable to occur.

Fatal accidents are often caused by the return of the miner before all the charges have gone off, or by drilling on to an unexploded charge or cartridge. If a number of reports corresponding to the number of charges are *not* heard, the miner should wait for at least thirty minutes before returning to the spot. When a number of charges have to be fired simultaneously a common cause of a misfire is the failure to light all the fuses. In such a case the unburnt fuse can be ignited and the charge exploded; but where the fuse may have burnt away and the charge still remain unexploded, if the tamping is sufficiently loose it should be carefully withdrawn and a fresh cartridge (with detonator and fuse attached) inserted above the old one; in almost every instance the whole charge goes off on explosion of the new cartridge. When the tamping cannot be easily withdrawn a new hole should be drilled some distance from the old one, great care being taken that the former is not drilled into the latter.

The dynamite fuse and detonating caps should be kept in a dry place, and never exposed to the direct rays of the sun.

In cold weather dynamite is liable to freeze, and in this condition is apt to explode when roughly handled; it should therefore be thawed before using, by placing it in a vessel surrounded by hot water and allowing it to stand for some time, away from fire.

It has not been considered necessary to give the method of using blasting-powder, as it is neither so safe nor so powerful as dynamite, and is seldom used for hard rocks. For dislodging coal blasting-powder is preferable to dynamite, as it does not shatter the coal into such small pieces.

Certain rocks can be broken down—although this is hardly blasting—by drilling holes in them and filling the holes with

water, then driving in quite dry wooden plugs, upon which water is again poured. The dry wood swells as a consequence, and if a sufficient number of these holes has been bored large fragments of the rock will split off. Much granyte is thus quarried on Dartmoor, and millstones are split off by means of moistened wooden wedges in France.

CHAPTER II

Useful Instruments; Hints upon Surveying, Water-power, &c.; Useful Calculation Methods; Tables, Glossary.

Certain instruments having been mentioned in the preceding pages, it will be necessary to explain their uses and the methods of employing them.

The aneroid barometer (fig. 131) is useful for measuring the heights of mountains and the depths of valleys, or the altitudes of towns or villages; also for ascertaining the fall between two given points in a river, and, in general, for determining the heights or difference in heights of all points, now readily accessible to the prospector for more accurate determination by means of a theodolite or level. It is a mechanical modification of the ordinary barometer explained on page 9 in Section I., and is marked with two scales, one showing the pressure of the atmosphere in inches, the other the corresponding height in feet above sea-level. Although not a very accurate means of determining heights it is a cheap and handy instrument for the prospector, who, before starting on an exploration, should have the instrument set by some proved standard barometer. The standard of atmospheric pressure at the sea-level at a temperature of 32 F. is 30·00 inches. Under similar conditions of the temperature and the atmosphere the barometer will show at a height of about 899 feet above sea-level a pressure of 29·00 inches, so that, as a rough calculation, the barometer may be assumed to fall 1 inch

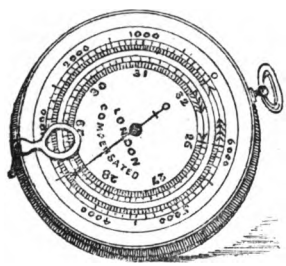


Fig. 131.—The Aneroid Barometer.

for every 900 feet of ascent. For more accurate readings and the various adjustments necessary to obtain them, the student is referred to 'Trautwine' or 'Molesworth' pocket-books.

The clinometer is a small instrument which can either be purchased in metal or vulcanite, or made out of stiff cardboard, and is used for measuring the dip or angle of inclination of strata, mineral deposits, veins, or the outline of a mountain range, &c. It is shown in its simplest form in fig. 132.

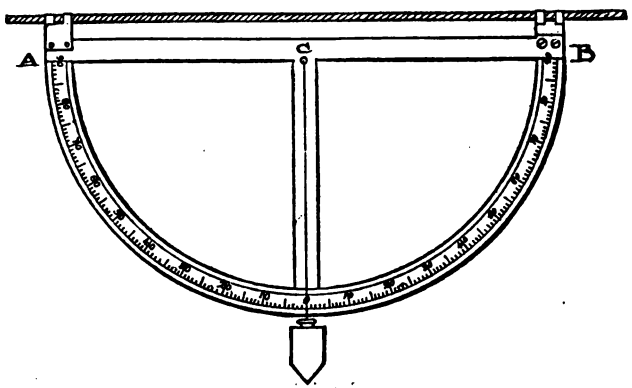


FIG. 132.

On a rectangular plate or card a semicircle is drawn from the centre C, passing through A and B. From C a weighted line is let drop perfectly plumb, and at right angles to A B, the line where it crosses the circle being carefully marked O, as in the figure. The arc is then divided into ninety equal parts between O and A, and into a similar number between O and B. The method of using it is as follows. The lower edge of the clinometer is placed upon the line of the dip of a stratum or lode, the pendulum being allowed to swing freely. When perfectly steady it will be found to pass over or approximate to a certain one of the degrees graduated upon the arc, and this number of degrees will represent the angle of inclination or the dip of the strata or lode *with the horizon* (see fig. 133, p. 260).

Diagram (fig. 134) shows the position in which to sink a shaft to strike a lode of which the dip is known, at any required depth.

Example.—Dip of lode 70°. Required, to strike same at a depth of 75 feet below the horizontal surface. Follow the angle of 70° on diagram downwards until the horizontal line opposite the 75 feet on the vertical scale is reached (point z on diagram). Then the distance between z and the right-hand margin is equal to the distance from the outcrop at which the required shaft must be started, in this case 27 feet 6 inches.

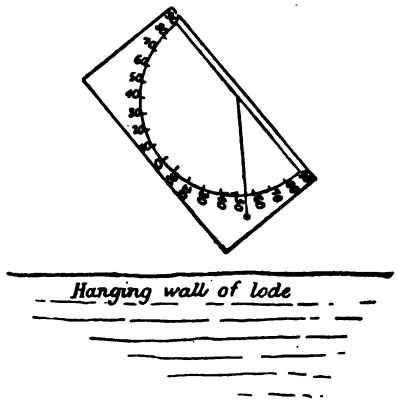


FIG. 133.

Should the surface rise from the outcrop, the point z would be the proportionate number of feet higher on the line of 70°; should it fall, z would be similarly lower.

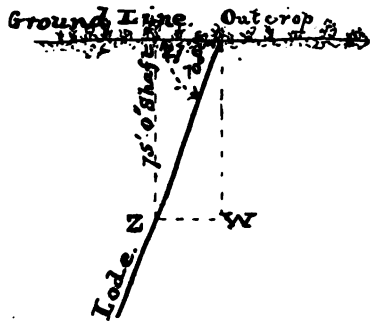
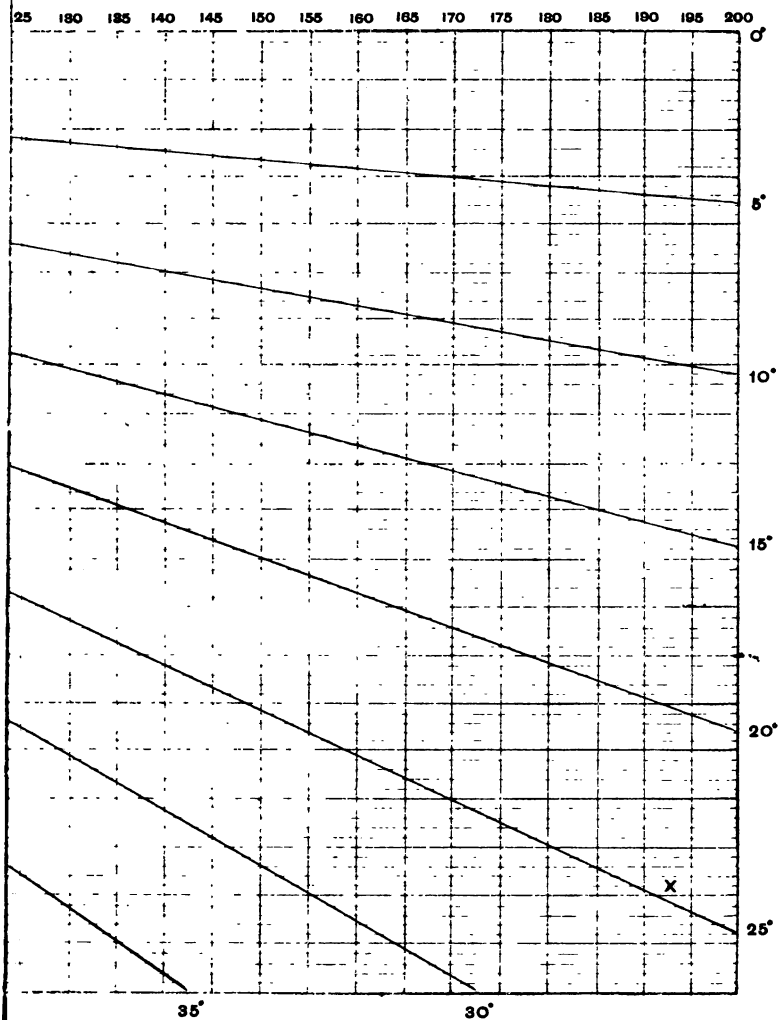


FIG. 134.

Diagram (fig. 134) shows the length an adit will require to be driven in order to enable it to strike a lode of which the dip is known, at any required depth.

SHAFTS.



DE OF WHICH THE DIP IS KNOWN

RDER TO ENABLE IT TO CUT A LODE
FROM THE SURFACE.
FEET.

Example.—Dip of lode 60°. Angle of slope of hill 25°. Required, to strike the lode at a vertical depth of 90 feet below the outcrop. Follow the angle of 25° downwards until it intersects the horizontal line of 90 feet depth (x on diagram). Then follow the line horizontally until it intersects the angle of 60° (w on diagram). The distance from x to w is equal to the length of the required adit, in this case 140 feet.

Should the lode dip away from the slope of the hill, the distance required will be the full length from x to the vertical column *plus* the number of feet from the vertical column to the same angle of dip on the diagram as the lode makes *beyond* the vertical.

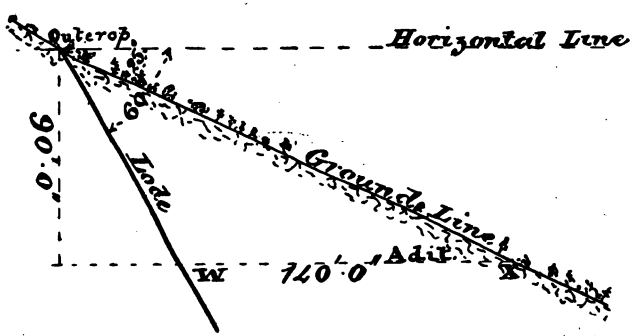


FIG. 135.

The prismatic compass is a very handy and useful little instrument. It consists of a glass-covered box containing a card to which a magnetic needle is attached, the card being graduated in degrees and thirds of a degree (or 20 seconds). A prism, A, is attached to one side of the cover and a threaded sight, B, is placed exactly opposite, a sliding reflecting mirror being attached. The entire circle is graduated *from the* S, and proceeds towards the right hand until it reaches the S again, or 360°. The instrument is used by holding it in the hand, and, while glancing through A, bringing the threaded sight B

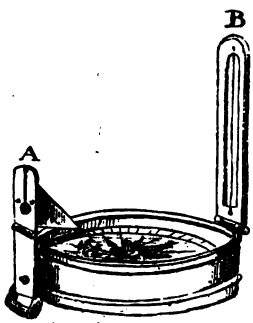


FIG. 136.—Prismatic Compass.

exactly in line with the object under observation; the gradations on the card will then be seen, by means of the reflector, in continuation of the thread, and the reading thus obtained will be the number of degrees *east of north* which a line passing between the observer and the observed will contain with a line passing from the observer to the *magnetic* north.

Let us suppose, for example, that the angle of a line passing between a stone, A, and flag, B (in fig. 137), is found to be 207° east of north, and, further, that the angle along a line from the stone A to the tree C is found to be 274° east of north; then the interior angle between these two lines (i.e. the angle at *d*) will be 67°, and the angle between the line A C and the magnetic north point (i.e. the angle at *e*) will be 86°.

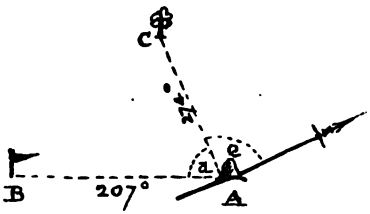


Fig. 137.

By the use of this instrument in the manner described above, and in combination with a tape or chain, very fairly accurate surveys can be made, in which the chief topographical features of the country can be approximately laid down.

It frequently happens that a shaft is being sunk from the crown of a hill while a tunnel is being simultaneously driven to intercept it. If an angle be carefully taken with the prismatic compass from the centre of the entrance to the drive

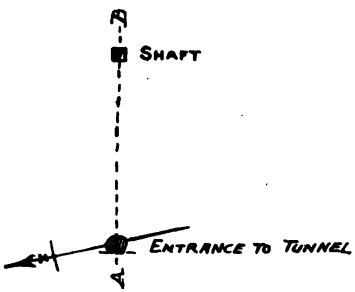


Fig. 138.

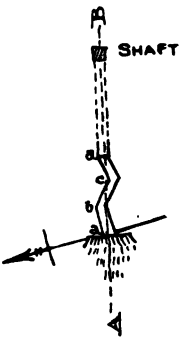


Fig. 139.

along a direct line terminating at the centre of the shaft overhead, and if the centre line of the tunnel while being driven

is kept in the same direction, there will be no awkward junction between tunnel and shaft.

For example, in fig. 138 the angle along the line A B with the magnetic north is 91° E. In driving the tunnel as in fig. 139 it will be seen that between *a* and *b* the tendency has been to the north, while between *b* and *c* the tendency has been too much to the south. By means of the compass this error has been detected, with the result that the section *c* to *d* is again in the right direction, as is shown by the fact that the line from the centre of the breast of the drive to the centre of the entrance is 91° E. of magnetic north.

The ordinary or Gunter's chain, used in surveying, contains 100 links, and measures 66 feet in length.

Useful Methods of Calculating, approximately, Areas, Quantities, Distances, &c.

To ascertain the average of any plot of ground, divide the number of square links by 100,000.

Example:—

$$605 \times 200 \text{ links} = \frac{121{,}000}{100{,}000} \text{ square links} = 1{\cdot}21 \text{ acre.}$$

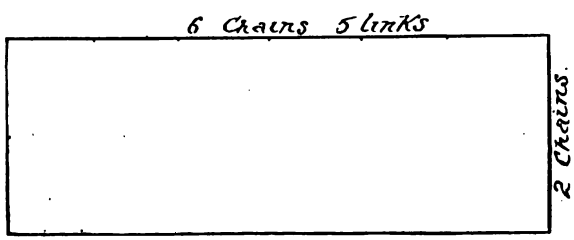


Fig. 140.

To find the area of any triangular piece of ground, multiply the base by the perpendicular, and divide the result by two.[1]

Example:—

A B = 450 links.
D C = 200 „

[1] The perpendicular is a line at right angles to the base from the angle opposite.

Then

$$\frac{450 \times 200}{2} = \frac{\text{Square links } 90{,}000}{2} = \frac{\text{Square links } 45{,}000}{100{,}000} = 0{\cdot}45 \text{ acre.}$$

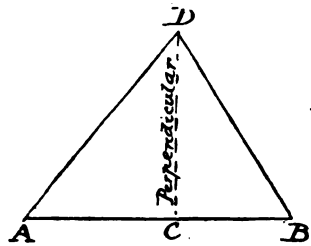


FIG. 141.

Should a plot of land be very irregular in outline its acreage can be calculated by dividing it up into a number of conveniently arranged triangles, averaging the very irregular lines, as in fig. 142. Each triangle is then measured sepa-

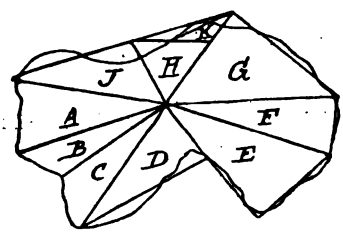


FIG. 142.

rately, and the sum of the results will equal the total area of the ground.

To continue a straight line beyond an obstruction:

Let AB be a straight line, and CD its required continuation. At B set out a line at right angles to AB, and at E set

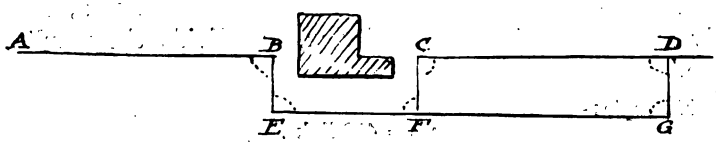


FIG. 143.

one out similarly at right angles to BE; at F set out another at right angles to EF, and parallel to BE, and let FC be equal

in length to B E. At C set out a right angle with F C, and this will be the continuation of A B. Prolong E F to G, and set out the right angle F G D. Then if G D is equal in length to B C and F C, the line C D is correctly set out.

A simple method of setting out a right angle is shown in fig. 144. The figures there given are either feet, yards, or chains, according to the length of the line required.

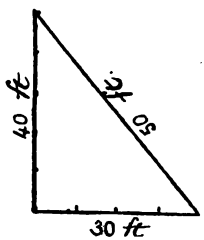


FIG. 144.

To ascertain approximately the distance between two points, one of which is inaccessible—a river, for example. Upon the edge of the opposite bank fix upon some easily seen object opposite to your position at A. Walk along the bank at right

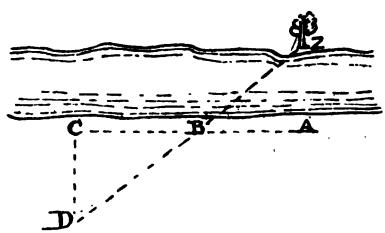


FIG. 145.

angles for a distance equal to what you consider to be the breadth of the river, and set up a mark, B. Continue for a similar distance from B to C. Then walk at right angles until you reach a point, D, which is in line with B and the inaccessible object. The length from C to D will equal that from A to Z in fig. 145.

To calculate approximately the number of tons of ore 'in sight' in a lode.—Multiply the height in feet from the lowest working to the outcrop by the distance in feet between the extreme points at which the lode has been proved Multiply this

result by the *average* proved width of the lode in feet, and divide by 20. The result will be the number of tons.

Example :—

Height (fig. 146)	100 feet.
Greatest length (fig. 146) . .	160 „
Average width (proved) . . .	$1\frac{1}{2}$ „

Then

$$100 \times 160 \times 1\tfrac{1}{2} = 24{,}000 \text{ cubic feet}$$

and

$$\frac{24{,}000}{20} = 1{,}200 \text{ tons } \textit{in sight.}$$

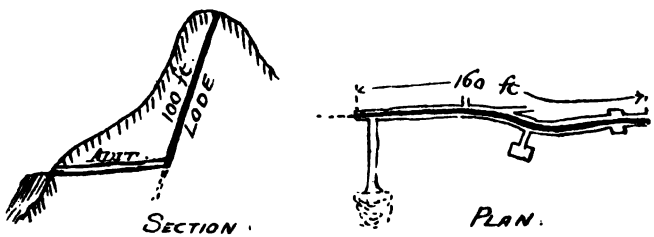


FIG. 146.

To calculate the number of tons in a dump of ore, it is necessary to divide the number of contained cubic feet by 22. Where the ore dump is rectangular the calculation is so simple as to need no describing.

Example (fig. 147).—Multiply the width of the dump AB by the length AC, both in feet. Multiply this result by one-third the perpendicular height ED, and divide by 22.

Thus :—

$$AB = 70 \text{ feet.}$$
$$AC = 135 \text{ „}$$
$$ED = \frac{45}{3} = 15 \text{ „}$$

Then

$$70 \times 135 \times 15 = 141{,}750 \text{ cubic feet}$$

and

$$\frac{141{,}750}{22} = \text{tons } 6{,}443{\cdot}1.$$

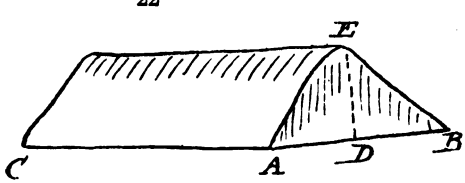


FIG. 147.

The same principle may be applied (dividing the number of cubic feet by 20) to calculate the number of tons of overburden to be removed in order to get at an ore deposit known to exist beneath.

Example.—Multiply the width A B in feet by the distance along which it is intended to uncover the ore in feet, and multiply the result by one-third the calculated distance from C to D. The result will be one-half of the number of cubic feet of overburden to be removed, which, divided by 20, will give the approximate number of tons *of one-half* of the overburden.

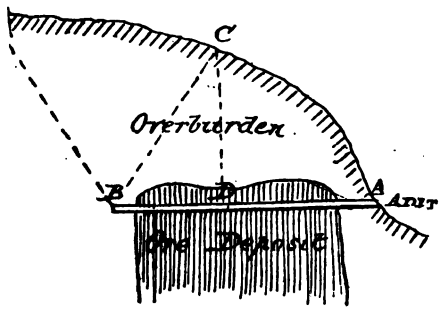


FIG. 148.

WATER POWER.

To measure approximately the volume of a stream or river by means of its velocity.—Set up on the bank of the river where the current appears to be steady, and of an average velocity from bank to bank, two poles, P P¹ (fig. 149), and measure the

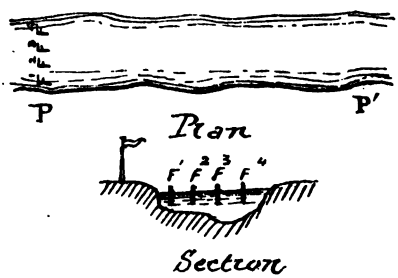


FIG. 149.

distances between them. Place in the river four or five floats of wood (F^1, F^2, F^3, F^4) (one at a time where the operation

has to be carried out unaided), and let them be weighted at the bottom in order that they may maintain an upright position. Note the time that each of the floats takes to pass from P to P^1.

Calculate the average depth and breadth of the river, and multiply the area thus obtained in square feet by the mean observed velocity of the floats in feet per second, which will give the total discharge of the river.

Example (fig. 149):—

	Secs.		Velocity in feet per second
Velocity of F^1 between P and P^1 (100 feet)	= 100	=	1
" F^2 " "	= 50	=	2
" F^3 " "	= 50	=	2
" F^4 " "	= 100	=	1
			4) 6
Showing a mean velocity in feet per second of . . .			1·5

Average width of river 35 feet
× " depth " 3
105 square feet × 1·5 = 157·5

which is the discharge of the river in cubic feet per second.

To calculate the horse-power available, using the data of the last example.—Multiply in feet the number of cubic feet discharged per minute by the fall between any two points. Multiply this result by the weight of a cubic foot of water (62·3 lbs.), and divide by 33,000.

In the last example we had a total discharge of 157·5 cubic feet per second. Then 157·5 × 60 = 9,450 cubic feet discharged per minute, and 9,450 cubic feet × 20 fall in feet × 62·3 ÷ 33,000 = 362·5 h.-p. in river.

It must be noted, however, that this is but the *theoretical* horse-power. From a turbine or an overshot water-wheel not more than one-half of this will be obtained, and from an under-shot wheel not more than one-third.

Weights and Measures.

Apothecaries' Weight.

20 grains	=	1 scruple.
3 scruples	=	1 dram.
8 drams	=	1 ounce.
12 ounces	=	1 lb.

Avoirdupois Weight.

27·34375 grains	=	1 dram.
16 drams	=	1 ounce.
16 ounces	=	1 lb.
28 lbs.	=	1 quarter.
4 quarters	=	1 cwt.
20 cwt.	=	1 ton.

Long Measure.

12 inches	=	1 foot.
8 feet	=	1 yard.
5½ yards	=	1 rod (pole or perch).
40 rods	=	1 furlong.
8 furlongs	=	1 mile.
8 miles	=	1 league.

Square or Land Measure.

144 sq. inches	=	1 sq. foot.
9 „ feet	=	1 „ yard.
30¼ „ yards	=	1 „ rod.
40 „ rods	=	1 „ rood.
4 „ roods	=	1 „ acre.

Cubic or Solid Measure.

1728 cubic inches	=	1 cubic foot.
27 „ feet	=	1 „ yard.

Capacity Measure.

						Avoir. lbs. of water		Cubic ins.
4 gills	=	1 pint			=	1·25	=	34·6
2 pints	=	1 quart			=	2·50	=	69·3
2 quarts	=	1 pottle			=	5·00	=	138·6
2 pottles	=	1 gallon			=	10·00	=	277·3
2 gallons	=	1 peck	Dry measure		=	20·00	=	554·5
4 pecks	=	1 bushel	Dry measure		=	80·00	=	2218·2
4 bushels	=	1 coomb	Dry measure		=	320·00	=	8872·8
2 coombs	=	1 quarter	Dry measure		=	640·00	=	17745·6

Metric Weights and Measures.

Long Measure.

Kilometre	=	1000 metres = 1093·623 yards.	
Metre	=	39·37	inches.
Decimetre	=	3·937	,,
Centimetre	=	·3937	,,

Square Measure.

Square kilometre	=	1000 square metres = 1196·011 square yards.
Square metre	=	1550·03 square inches.
Square centimetre	=	·1550 square inch.
Square millimetre	=	·00155 square inch.

Weights.

Kilogramme	=	2·2046	lbs. avoirdupois.
Gramme	=	15·432	grains ,,
Centigramme	=	·15432	,, ,,
Milligramme	=	·01543	,, ,,

Melting Points of Metals in degrees Fahr.

Antimony	955	Lead	612
Bismuth	506	Mercury	−39
Brass	1873	Silver	1861
Copper	2000	Steel	2370–2500
Gold	2016	Tin	444
Iron (cast)	1920–2800	Zinc	680–772
Iron (rolled)	3000–3500		

Weights of various Substances in Pounds per Cubic Foot.

Substance	Weight	Substance	Weight
Alabaster	144	Boxwood	80
Aluminium	162	Brass	510
Anthracite	90	Bricks	125–150
Antimony	416	Calcite	169
Ash	47	Cement (hydraulic)	100
Basalt	181	Chestnut	41
Bath Stone	131	Coal	84
Bismuth	607	Copper	550
Bitumen	85	Earth (dry)	72–80

Substance	Weight
Ebony	76
Elm	35
Feldspar	166
Flint	162
Glass	160
Gneiss	168
Gold	1206
Granyte	170
Greenstone	190
Gypsum	141
Hickory	53
Hornblende	208
India-rubber	58
Iron (cast)	446
Iron (wrought)	485
Ivory	114
Lead (cast)	709
Lignum Vitæ	83
Lime (quick)	53
Limestone	160–170
Mahogany (Spanish)	53
Mahogany (Honduras)	35
Marble	170
Masonry (Granyte or Limestone)	165
Masonry (Rubble)	150
Masonry (Brick)	140
Mercury	840
Mica	183
Mud (dry)	80–110
Mud (wet)	110–130
Naphtha	53
Oak (white)	48
Oak (red)	32–45
Oak (black)	35–47
Oil (Turps)	54
Oil (Olive)	57
Oil (Petroleum)	20–30
Pine (white)	25
Pine (red)	34
Pitch	71
Platinum	1342
Porphyry	170
Quartz	165
Salt (coarse)	45
Sand (dry)	90–106
Sand (wet)	117
Sandstone	130–170
Serpentine	162
Shale	160
Silver	655
Slate	175
Snow	5–12
Soapstone	170
Spelter	437
Spruce	25
Steel	490
Sulphur	125
Sycamore	37
Tar	62
Tin	459
Trap Rocks	190
Turf or Peat (dry)	20–30
Walnut	38
Water (rain)	62·3
Water (sea)	64·08
Zinc	437

VARIOUS THERMOMETER SCALES.

The zero on both Centigrade and Réaumur scales is coincident with 32° on the scale of Fahrenheit.

To change Fahrenheit degrees to Centigrade.—Take a Fahrenheit reading 32 degrees lower than the given one, then multiply by 5 and divide by 9.

Example :—

104° Fahr.
32° Coincident with 0° on Centigrade.
72° × 5 ÷ 9 = 40° Centigrade.

To change Fahrenheit degrees to Réaumur.—Take a Fahrenheit reading 32 degrees lower than the given one, then multiply by 4 and divide by 9.

Example :—

104° Fahr.
32° Coincident with 0° on Réaumur.
72° × 4 ÷ 9 = 32° Réaumur.

To change Réaumur or Centigrade scales to Fahrenheit the process must be exactly reversed, not forgetting to *add* the 32 degrees.

To change Centigrade to Réaumur × 4 ÷ 5.
To change Réaumur to Centigrade × 5 ÷ 4.

Example :—

40° Centigrade
4
5) 160
32° Réaumur (see above).

THE VEGETABLE AND ANIMAL KINGDOMS.

(Inserted with the object of assisting the student to classify his fossils correctly.)

The Vegetable Kingdom.

Division 1. *Cellular.*—The lowest of all plant life; plants which have no regular vessels, but are composed of fibres which sometimes cross and interlace one another.

Examples: *Confervæ.*—Green vegetable scum often seen on the top of stagnant water.

Lichens.—Green, grey, and red vegetable covering on stones.

Fungi.—Mushrooms &c.

Algæ.—Sea-weeds.

DIVISION 2. *Vascular.*—Plants with vessels for the purposes of reproduction and nutrition. Divided into two sections.

A. Cryptogamic (*Flowerless*).
B. Phanerogamic (*With flowers*).

Examples of *Cryptogamic* plants are mosses, ferns, horse-tails (equisetums), lycopods, adders'-tongues, moonworts, &c.

Phanerogamic plants are divided into three classes:

(a) *Gymnosperms* (*with naked seeds*), such as cycads, firs, &c.

(b) *Monocotyledons* (*having one seed-lobe*), such as lilies, aloes, grasses, canes, palms, rushes, &c.

All the above increase their growth *within*, and are therefore termed *Endogens*.

(c) *Dicotyledons* (*having two seed-lobes*), such as elms, planes, laurels, lotus plants, crows-foot, nightshade, mint, lavender, olives, cucumbers, gourds, primroses, heaths, proteas, peas, beans, cloves, apples, figs, almonds, walnuts, and all the higher types of plant life.

These increase their growth by means of successive layers added *externally*, and are therefore termed *Exogens*.

The Animal Kingdom.

Division 1. Vertebrata.
Division 2. Invertebrata.

Vertebrata, or animals with backbone and bony skeleton.

A. Mammalia, Animal-sucklers.
B. Aves, Birds.
C. Reptilia, Reptiles.
D. Pisces, Fishes.

A. *Mammalia.* (a) *Placental, bringing forth mature young.*

Bimana (*two-handed*), man.

Quadrumana (*four-handed*), monkeys, apes, lemurs.

Cheiroptera (*wing-handed*), bats, vampires, flying foxes.

Insectivora (*insect-eaters*), moles, shrews, hedgehogs.

Carnivora (*flesh-eaters*), dogs, wolves, lions, tigers, seals, walrus.

Rodentia (*gnawers*), hares, beavers, squirrels, porcupines, rats.

Edentata (*toothless*), ant-eaters, armadillos, sloths.

Ruminantia (*cud-chewers*), camels, llamas, oxen, deer, sheep, goats.

Solidungula (*solid hoofs*), horses, asses, quaggas, zebras.

Pachydermata (*thick skins*), elephants, hippopotami, rhinoceri, pigs.

Cetacea (*whales*), whales, porpoises, dolphins.

(b) *Aplacental, bringing forth immature young.*

Marsupialia (*pouched*), kangaroos, opossums.

Monotremata (*one-vented*), ornithorhynchus, porcupine-ant-eater.

B. *Aves* (*Birds*).

Raptores (*seizers*), eagles, falcons, hawks, owls.

Insessores (*perchers*), jays, crows, finches, sparrows, thrushes, &c.

Scansores (*climbers*), parrots, cockatoos, woodpeckers.

Columbæ (*pigeons*), doves, pigeons, &c.

Rasores (*scrapers*), partridges, pheasants, fowls, grouse.

Cursores (*runners*), ostriches, emus.

Grallatores (*waders*), rails, storks, cranes, herons.

Natatores (*swimmers*), divers, ducks, geese, gulls.

C. *Reptilia.* (a) *Reptiles proper.*

Chelonia (*tortoises*), turtles, tortoises.

Loricata (*covered with plates*), crocodiles, alligators.

Sauria (*lizards*), lizards, chameleons, iguanas.

Ophidia (*serpents*), vipers, various snakes, boa-constrictors.

(b) *Amphibians* (living both on land and in water).

Anoura (*tail-less*), toads and frogs.
Urodela (*with tails*), tritons, salamanders.
Apoda (*footless*), blind worms.

D. *Pisces.* (*Fishes*).

Salachia (*cartilaginous*), sharks, rays, sawfish.
Ganoidea (*enamel-scaled*), bony pike, gar pike, sturgeon.
Teleostia (*perfect-boned*), eels, salmon, herring, cod, &c.
Cyclostomata (*round-mouthed*), lamprey.
Leptocardia (*slender-hearted*), amphioxus.

Invertebrata, or animals having no backbone or bony skeleton.

A. Mollusca, Shell Fish.
B. Articulata, Jointed Animals.
C. Radiata, Ray-like Animals.
D. Protozoa, Globular Animals (lowest form of life).

A. *Mollusca.* (a) *Mollusca, or shell-fish proper.*

Cephalopoda (*head-footed*), cuttles, octopi, nautili.
Pteropoda (*wing-footed*), clio, hyalæa.
Gasteropoda (*belly-footed*), snails, slugs, whelks, cowries.
Acephala (*head-less*), oysters, mussels, cockles.
Brachiopoda (*arm-footed*), terebratulæ, lingulæ.

(b) *Molluscoida, or mollusc-like.*

Tunicata (*coated but shell-less*), ascidians.
Polyzoa (*compound animals*), flustra, eschara, plumatella.

B. *Articulata.* (a) *Articulata, or Jointed animals proper.*

Insecta (*insects*), beetles, butterflies, flies, bees, wasps, &c.
Myriapoda (*many-footed*), centipedes, millipedes.
Arachnida (*spiders*), spiders, scorpions, mites.
Crustacea (*crust-clad*), lobsters, crabs, shrimps, woodlice.
Cirrepedia (*curled-feet*), barnacles.

(b) *Vermes, or Worms.*

Annelida (*small-ringed*), lobworms and marine worms.
Rotifera (*wheel-bearers*), rotifers, hydatina.
Gephyria (*urchin-like, intermediates*), echinus.
Lumbricina (*earth-worms*), earth-worms.
Hirudinei (*leeches*), leeches.
Turbellaria (*turbellaries*), ribbon worms.
Helminthes (*gut worms*), intestinal (tape) worms.

C. *Radiata* (*zoophytes*).

Echinodermata (*urchin-skinned*), echini, starfish, encrinites.
Acalephæ (*sea-nettles*), jellyfish.
Polypi (*many-feet*), coral animals, anemones, hydræ.

D. *Protozoa* (*lowest life*).

Infusoria (*infusories*), monads, vorticella, volvoces.
Porifera (*pore-bearers*), sponges.
Rhizopoda (*root-footed*), foraminifera.

A GLOSSARY OF MINING TERMS.

A

Acicular.—Needle-shaped.
Adamantine.—Of diamond lustre.
Adit.—A horizontal entrance to a mine from a hill-side.
Adventure.—The Cornish term for a mining enterprise.
After-damp.—Carbonic acid gas, suffocating and deadly.
Alkalies.—The minerals potash, soda, lithia, &c. They neutralise acids and form salts. They precipitate hydrates from their salts.
Alloy.—A fused mixture of two or more metals.
Alluvium.—A water-deposited accumulation of silt, sand, gravel, &c.
Amalgam.—A mechanical combination of mercury with another metal.
Amygdaloid.—Almond-shaped.
Analysis.—The resolution of compound into simple substances.
Anhydrous.—Without water.
Anticlinal.—Strata sloping away on either side of a given centre.
Arenaceous.—Sandy.
Argillaceous.—Clayey.
Assay.—A process for ascertaining the percentage of a metal or metals in an ore or alloy.
Attal.—The waste of a mine; débris.
Auriferous.—Gold-bearing.

B

Back.—The extent of a lode between the roof of a level and the surface.
Bal.—A Cornish term for a mine.
Bank Claim.—A claim on a river-bank.
Bar.—A course of rock crossing a lode; an obstruction in a river-bed.
Basset.—An outcrop.
Battery.—A stamp-mill.
Bed Rock.—The solid formation beneath recent deposits.
Belly.—A swelling in a lode.
Black Sand.—Generally, iron in some form.
Black Tin.—Tin ore ready dressed for smelting.
Blanket Sluices.—Those in which blankets are employed to arrest fine gold.
Blast.—Air forced into a furnace.
Blasting.—The breaking of rocks by explosives.
Blind Creek.—A creek dry except after freshets.
Blind Lode.—One that does not outcrop.

Blossom.—Coloured stone from outcrop.
Blue Billy.—The residue of copper pyrites after roasting.
Blue Elvan.—Greenstone.
Blue John.—A variety of fluorite.
Bonanza.—A rich ore body.
Bonnet.—The cover of a cage.
Botryoidal.—Grape-like.
Boulders.—Large rocks derived from masses.
Branch.—A string of ore connected with a lode.
Breach.—The face of a level.
Breasting.—Taking ore from the breach.
Breccia.—A cement composed of angular fragments.
Brooch.—A mixture of various ores.
Buddle.—An ore-concentrating apparatus. There are numerous varieties of buddles.
Bunch.—A small ore body.
Button.—The resultant globule of metal from an assay.

C

Cage.—An elevator for raising or lowering men and ore in a mine.
Calcine.—To heat gently.
Cap.—The formation above the valuable portion of a lode.
Captain.—The superintendent of a mine's workings.
Carat.—A weight of about 4 grains. A standard for judging gold alloys.
Carboniferous.—Coal-bearing.
Casing.—The material immediately adjoining a lode.
Caving.—The falling-in or collapse of mine workings.
Caunter.—A lode crossing a main lode.
Cellular.—Containing cells or cavities.
Claim.—A mining property.
Clean-up.—The valuable product collected after an ore has been treated.
Cleavage.—The property of separating into layers.
Cobbing.—Breaking ore into small fragments.
Collar.—The timbers placed around the mouth of a shaft.
Concentration.—A process of collecting the richest portions of an ore only.
Contact Vein.—(See page 144.)
Cord of Ore.—About seven tons, measured by *bulk*.
Cord of Wood.—128 cubic feet.
Cost-book System.—A system of mine partnership which allows an *adventurer* to pay his share of the mine's indebtedness and remove his name from the books.
Country-rock.—The rocks surrounding a mineral deposit.
Course.—The strike of a lode.
Cradle.—A simple apparatus for collecting alluvial gold.
Creek.—A small watercourse.
Cretaceous.—Chalky.

Crevicing.—The collection of gold or other minerals from the crevices of rocks.
Cross-course.—A vein of rock crossing the main lode.
Cross-cut.—A level driven at right angles to the course of a lode to intersect it.
Crusher.—A machine for breaking hard rocks.
Cuneiform.—Wedge-shaped.
Cupel.—A small vessel used by assayers.
Cupriferous.—Copper-bearing.
Cut (*to*).—To intersect a lode.

D

Dan (or *Corve*).—A sled employed for running ore along the levels of a mine.
Davy Lamp.—A patent safety-lamp for miners, invented by Sir Humphry Davy (see page 19).
Day Hole.—A passage cut from the side of a hill to the headings in a mine.
Day Water.—Surface water.
Deads.—Waste rock, débris.
Dead Work.—That which, although unproductive, is necessary.
Decomposed.—Resolved into elementary constituents.
Denudation.—Laid bare by the action of water or atmosphere.
Desiccation.—The act of drying.
Development.—The work undertaken to prove the extent of payable ground in a mine.
Dial.—A compass used in mine-surveying.
Dialling.—The act of using a dial for the purpose of surveying and mapping.
Die.—The iron upon which the stamps fall and crush the ore in a mortar box.
Diggings.—A generic term used to denote the site of gold-mines.
Dip.—The inclination of a vein with the horizontal.
Disseminated.—Scattered.
Ditch.—An aqueduct.
Dolly.—A rude apparatus for washing and crushing ores.
Downcast.—An opening down which pure air is passed into a mine for ventilation.
Dressing.—The preparation and sorting of ores for reduction.
Drift.—An underground tunnel.
Ductile.—Capable of being drawn out into extended length.
Dump.—A pile of ore or waste from a mine.
Dyke.—A vein of intrusive rock.

E

Elbow.—A sharp bend in rock formations.
Elvan.—A course of hard rock.

Entry.—The mouth of a tunnel or adit.
Exploit.—To develop a mine to ascertain its commercial value.
Eye of a Shaft.—The top.

F

Face.—The breast, or further end of a level or excavation.
Fan.—A machine employed to force air into a mine or furnace.
Fathom.—Six feet linear.
Fault.—A dislocation of strata (see page 134).
Ferric.—Extracted from iron.
Ferriferous.—Iron-bearing.
Flang.—A two-pronged fork.
Float-gold.—Minute flakes of gold which float on the surface of water, owing probably to a thin film of air on their under surfaces.
Float-stones.—Fragments of a solid formation broken off and scattered about the surface.
Floured.—A term used to express incohesive mercury.
Flume.—A wooden aqueduct.
Flux.—A substance employed to aid the fusion of metals.
Foot-wall.—The wall of rock on the *under* side of a vein.
Fork.—The bottom of a sump. A mine is 'in fork' when clear of water.
Free-gold.—Uncontaminated gold capable of amalgamation.
Free-milling Ore.—Ore which offers no difficulty to the detention of its gold or silver by amalgamation.
Freshet.—A sudden rise of water; flood-waters.
Friable.—Easily broken up.
Frue-vanner.—A patent concentrator for the treatment of ores.
Fuse.—A tube filled with combustibles, used for discharging explosives.
Fusible.—Capable of being melted.

G

Gad.—A small iron wedge.
Gallery.—A level *in* a mine.
Gang.—A party of miners.
Gangue.—The unprofitable matrix of a lode.
Gangway.—A main level or drift.
Goaf.—The worked-out parts of a mine.
Gouge.—A layer of clay or other soft material beside the walls of fissure vein.
Granulated.—In grains.
Grizzly.—An obstruction to the passage of large stones in a sluice.
Guides.—The timbers placed in a shaft to steady the cage.
Gully.—A steep ravine.
Gunnies.—The spaces left by stoping.

H

Hade.—The angle of inclination of a vein (see page 134).
Halvans.—Impure refuse of ores.

Hanging Wall.—The wall of rock on the *upper* side of a vein.
Heading.—The lode above a level.
Horse.—A barren intrusion into a vein or lode.
Hydraulicing.—Washing down gravel &c. by means of water under great pressure.

I

Impregnated.—Country rock with frequent ore inclusions.
Inch.—Ninety-five cubic feet of water discharge per hour. It is an arbitrary measurement in different countries.
Inclination.—Another name for dip.
Incrustation.—An external coating.
Iridescent.—Rainbow-like in play of colour.

J

Jigger.—A sieve suspended in water, and which being shaken forms a rude concentrator.
Jigging.—Using a jigger.
Jumping.—The act of acquiring an abandoned or non-legally held claim.

K

Kal.—A coarse kind of iron.
Kibble.—An iron bucket used for hoisting ores.
Killas.—A Cornish name for Silurian (?) clay slates.
Kiln.—An oven for drying or calcining.

L

Lagging.—Light timbers placed behind the 'sets' in a shaft or drive.
Lamina.—A thin slice or plate.
Lander.—The man who lands a raised bucket or kibble.
Leaching.—Extraction of metallic salts by the use of a solvent.
Lead.—An auxiliary vein or lode.
Leader.—Synonymous.
Ledge.—Synonymous with a vein or lode.
Lenticular.—Onion-shaped.
Level.—Literally, the horizontal passages or galleries driven at intervals *in* a mine.
Little Giant.—A movable nozzle on hydraulic hose.
Locate.—To mark out a claim.
Lode.—Literally, a fissure filled with metalliferous matter; *not* a gash vein (see page 141).
Long Tom.—An apparatus used in alluvial washing.

M

Malleable.—Capable of being beaten out.
Man Engine.—A machine by which miners can ascend and descend shafts.

Matrix.—Another name for gangue.
Matte.—The material resulting from the incomplete reduction of ore.
Metalliferous.—Metal-bearing.
Metallurgy.—The art of separating metals from ores.
Metamorphic.—Having undergone change.
Mill.—Usually used to denote a set of gold ore stamps.
Mock Ore.—A kind of false mineral.
Mortar.—The box (usually of iron) in which ores are pulverised.
Mouth.—The top of a shaft or end of an adit.
Muffle.—A small fire-proof furnace used in assaying.
Mullock.—Débris filling a fissure.
Mundic.—Iron pyrites.

N

Native Minerals.—Those minerals which are found uncontaminated and unalloyed; pure elements.
Noble Metals.—Generally speaking, gold, silver, the platinum group, and mercury.

O

Open-cut.—An open surface working.
Ore.—Minerals containing metals.
Outcrop.—The part of a lode, vein, or deposit which is apparent on the surface.
Output.—The yield of a mine.
Oxide.—(See page 11.)

P

Panning-out.—Separating gold from its matrix by means of a pan filled with water (see page 240).
Parting.—The separation of the gold from the silver after cupellation (see page 208).
Patch.—A small deposit of ore.
Pay-dirt.—Auriferous gravel which will pay for working.
Pay-streak.—The part of a lode or vein which will pay for mining and treatment.
Peach-stone.—A soft rock found in certain Cornish mines. 'Peachy' lodes are reckoned good ones.
Pillar.—A portion of a lode left as a support.
Pinch.—To contract in width.
Pitch.—The part of a lode let on tribute.
Placer.—An auriferous alluvial deposit.
Plant.—The machinery, fixtures &c. connected with a mine.
Pocket.—An isolated mineral deposit; *not* a vein.
Post.—Limestone strata divided horizontally with shale.
Precipitate.—The name given to the act of separating solid matter from a solution.
Props.—Timber supports for a roof in a mine.
Prospecting.—The searching for minerals.

Puddling.—A machine employed for mixing clays and fine gravel with water.
Pulverise.—To powder, to crush.

Q

Quarry.—An open excavation of some magnitude.

R

Race.—An artificial aqueduct.
Rake.—A fissure vein.
Reagent.—A substance employed to precipitate another by mutual action upon each other.
Reef.—A lode or vein (literally).
Refining.—Purifying crude metals.
Refractory.—Ores which offer unusual difficulty to their simple treatment.
Regulus.—The purest part of metals resulting from their fusion.
Reserves.—The amount of valuable ores left in a mine.
Retorting.—The separation of bullion from amalgam by action of heat.
Reverberatory Furnace.—One in which ores are placed and acted upon by heat forced down or back.
Riddle.—A large sieve.
Rider.—A piece of intrusive rock crossing and dividing a vein.
Riffles (*Ripples*).—Strips of hard wood nailed across a sluice to arrest gold in alluvial washings.
Rise.—An overhand stope.
Roasting.—A process employed with the object of volatilising impurities in an ore.
Roof.—The top of a level or drift.
Roughs.—Second-quality cross tin.
Royalty.—The rent paid for a mining property.
Run.—The yield per ton of ore.
Run of Lode.—Course; strike.
Rusty Gold.—Gold covered with iron-oxide.

S

Salting.—The introduction of good ore into a mine for purposes of deception.
Sample.—Specimens taken for assay.
Screen.—A fine sieve placed in front of a mortar, through which water and the crushed ore passes.
Seam.—A bed of coal.
Seat.—The floor of a level.
Sectile.—Readily cut.
Sett.—A block of mining claims; a claim.
Sheave.—A pulley.

Shift.—The number of hours which are worked in a mine. There are usually a *day shift* and a *night shift*, or sometimes three *eight-hour shifts*.

Shoding.—Tracing pieces of ore to the parent lode.

Shute (*Shoot*).—A rich body of ore in a vein; a passage through which ore is passed.

Sickened Mercury.—Mercury which has become contaminated by impurities and will not therefore amalgamate.

Sink.—To work downwards.

Slag.—The waste resulting from the smelting of ores.

Slide.—A downward disturbance of strata.

Slimes.—Ores crushed into pulp.

Slovan.—The outcrop.

Sludge.—Mud.

Sluice.—A trough in which auriferous sands and gravels are washed (see page 243).

Smalls.—Small-sized pieces of ore.

Spar.—A miner's name for quartz.

Spreaders.—The heavy timbers placed *horizontally* in a set, or those placed in a shaft as supports.

Spurs.—A small off-shoot from a lode.

Stamps.—Heavy pestles used in a machine for pulverising hard ores.

Stopes.—Literally, *steps*. The excavations made by which the lode is separated from the country rock.

Strake.—An inclined board used in the separation of gold and quartz powder.

Strike.—A finding of ore; the direction in which a lode runs.

String.—A thin course of ore.

Stull.—The timbers placed across the workings in a mine upon which packing is placed.

Sublimation.—The volatilisation of minerals by the action of heat.

Sumps.—Holes sunk at the bottom of shafts to hold the water.

Sun-lode.—A vein running southwards.

Swither.—A crevice branching from a main lode.

Synclinal.—Strata which dip from opposite directions to a common centre.

T

Tackle.—The rope, windlass, kibble &c. used in hoisting ore.

Tailings.—The lighter portions of an ore uncollected by the processes of washing.

Tail Race.—The channel by which the tailings are run off; the waterway from a water-wheel.

Tamping.—Clay or other material used to cover up an explosive previous to ignition.

Timbering.—The placing of timbers in workings for the purposes of safety, support, or merely for convenience.

Touchstone.—A hard stone used for testing the quality of gold and other alloys.
Trace.—To follow a clue in prospecting.
Trap-rock.—A generic term used to denote igneous or plutonic rocks of the basalt class.
Trend.—The course or strike of a vein.
Tribute.—A method of working or letting a mine upon payment of a percentage of the profits.
Tunnel.—A subterranean passage, strictly speaking, open at *both* ends.
Tye.—The junction point of two veins or lodes.

U

Underhand.—A stope beneath the feet.
Underlie.—Dip.
Unwater.—To drain the water from a mine.
Up-cast.—An opening up which the ventilating air passes out of a mine.

V

Vanning.—The washing of ores in a shovel; usually employed for testing tin ores.
Vapour.—Foul air.
Vein.—Another word for a lode.
Vein-stuff.—Ore and gangue mixed.
Vitreous.—Glassy.
Volatile.—Capable of readily passing into vapour.
Vuggy-lode.—A hollow lode.

W

Walls.—The boundaries of a lode (see page 142).
Wash-dirt.—Auriferous gravel or sand, &c.
Waste.—Old workings.
Wheal.—A Cornish name for a mine.
Whim.—An apparatus (usually worked by a horse) for raising ore from a mine.
Whip.—A similar apparatus, but instead of being worked in a rotary manner, the traction is at right angles to the drop of the line or rope.
Winding Engine.—The engine which raises the cages in a mine.
Windlass.—A simple hoisting-machine.
Windsail.—A canvas pipe used for ventilating shafts and drives.
Winze.—A shaft, unconnected with the surface, joining the levels in a mine.
Workings.—Development operations, shafts, drives, &c.

Z

Zigger.—A stream of water percolating through a crack.

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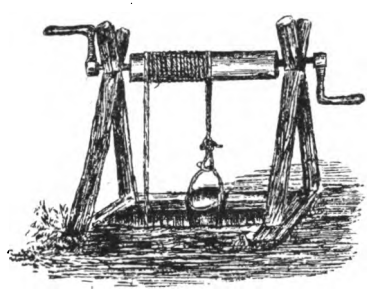

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